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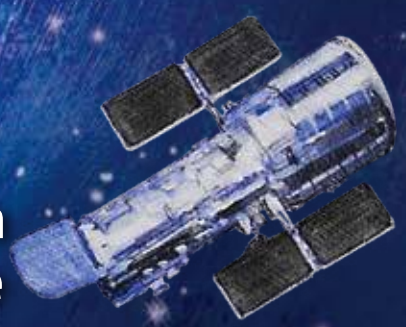

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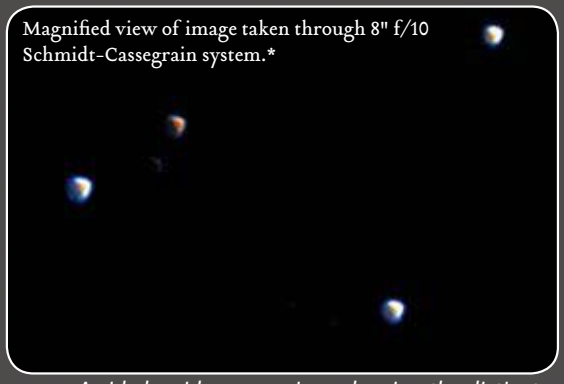

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CGE Pro 1100	11087	2800 mm f/10	40 mm – 1.25" (70x)	9x50	Starbright XLT	11" Schmidt-Cassegrain	Aluminum	204 lbs
CGE Pro 1400	11088	3910 mm f/11	40 mm – 1.25" (98x)	9x50	Starbright XLT	14" Schmidt-Cassegrain	Aluminum	243 lbs
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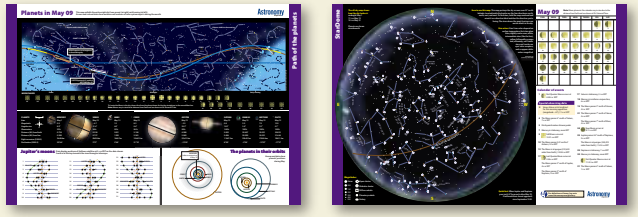
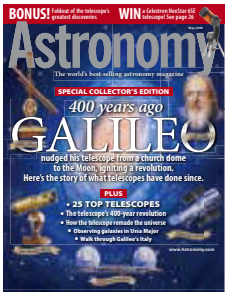


Path of the planets and StarDome.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• Observing galaxies in Ursa Major
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ON THE COVER

Galileo Galilei launched a scientific revolution in 1609 when he first turned his new telescope toward the sky. In the 400 years since, astronomers have used this tool to solve the greatest cosmic mysteries. Cover: Robb Helf

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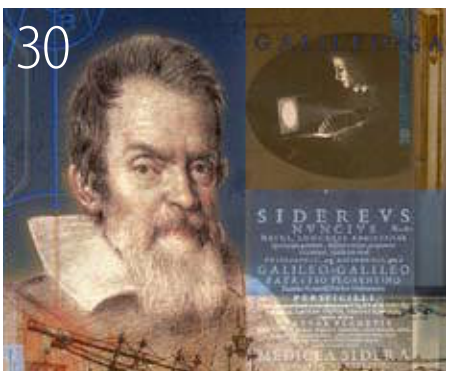

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A tale of two contests

by David J. Eicher

It's not too late to enter *Astronomy*'s 2009 Astroimage Contest, which you may have read about in last month's issue or on our web site, Astronomy.com. The deadline is fast approaching — April 15, 2009! You probably will have received this issue during the first week of April, so you may have time yet. But be quick! By sending us your best shots, you might win one of several prizes. The grand prize is a 5-night stay at Arizona Sky Village in Portal, Arizona, or Rancho Hidalgo Astronomy Village in nearby Animas, New Mexico (worth $3500), plus $1,000 to cover airfare, a rental car, and food. Who wouldn't like to have a trip to the darkest of skies in the United States to observe with large telescopes there?

The Astroimage Contest categories are Deep-Sky, Solar System, and General. To enter, please submit digital images online at Astronomy.com/photocontest. You can also send images on a CD or DVD to: Astronomy Photo Contest, P. O. Box 1612, Waukesha, WI 53187–1612.

The image must feature an astronomical object in one of the three categories — one entry per contestant — and please include a description of the subject featured, the name and address of the imager, equipment used, and exposure time(s). Composite images (those made from multiple exposures) are allowed.

The top prize in each of the three categories is pretty sweet, too. There's a set of four nebular filters (Deep-Sky, UHC, OIII, and Hβ) from Lumicon, valued at $400, for the Deep-Sky winner. The Solar System champion will receive a 1¼" Hydrogen-alpha filter from Astrodon Filters worth $275. The top shooter in the General category will win a 13mm Ethos eyepiece worth $620 from Tele Vue Optics.

In another direction, I'm pleased to announce the winners of our recently concluded Young Astronomer's Video Contest held this past December and sponsored by the magazine, The National Earth Science Teachers Association, and Celestron. Some 37 entries came in from middle schools and high schools around the country, placed in the categories of 6th- to 8th-grade students and 9th- to 12th-grade students. The task was to produce a video that communicates an astronomical theme.

Visitors to Astronomy.com chose the two grand-prize champions. The middle school winner was a submission from Oliver Middle School in Broken Arrow, Oklahoma, that focused on Pluto and whether or not it should be classified as a planet. The victor in the high school class was a team from Prairie School in Racine, Wisconsin.

The first-place-winning school in each category received a Celestron Sky Scout while each team member received Celestron Travelers 10x26 binoculars. Congratulations to the winners! To see the top films, check out Astronomy.com/youngastronomers.

I hope you enjoy this special telescope issue, the first of a few things we'll be doing during this International Year of Astronomy. In addition to the great articles in this issue, check out the events sponsored by the International Astronomical Union at astronomy2009.org.

Now send in those astrophotos!

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 37, Number 5

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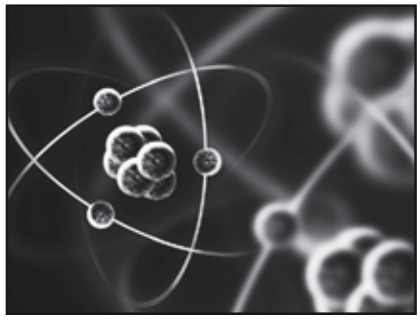

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Professor Benjamin Schumacher is Professor of Physics at Kenyon College. In 2002, he won the Quantum Communication award, the premier international prize in the field of quantum mechanics.

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Todd-White Art Photography/ Jay Jopling/White Cube (London)

Astroinfluences

How did you get interested in cosmology-inspired art?

Island Universe stems from some 1960s chandeliers that hang in both the theater and atrium of the Metropolitan Opera House in New York. My impression of them during my first evening at the opera was that they looked like pop images of the Big Bang. That night, I had this notion: "Gosh, wouldn't it be interesting to try to remake these things? But instead of being an impression of an explosion or a galaxy built intuitively, it would actually have a one-to-one relationship with the science of the Big Bang." It was a crazy notion.

An open-ended collaboration with the Ohio State University connected me with David Weinberg, an astronomy professor and cosmologist there. Initially, the project seemed impossible: How do you visualize an expansion of space and time in three dimensions? But it turned out my original sketch that I had shown to David actually made sense — the drawing suggested that you were looking at more than one moment in time. My drawing implied a slide show of the history of the universe.

Interestingly, my intuition about these chandeliers wasn't so strange. They were designed in 1965, which is the year of the discovery of the cosmic microwave background. I eventually learned that the original chandeliers had been redone in response to what was happening in the popular press about astronomy. So it actually wasn't so crazy that I made that connection. That's a lot of my work: overlaps in history in which ideas influence different fields in ways you wouldn't expect.

Photo courtesy Josiah McElheny

Josiah McElheny

Artist of the traveling exhibit *Island Universe*, a set of abstract sculptures that creates a scientifically accurate model of the Big Bang

Astroideas

Where is the study of galaxies going?

Our efforts focus on how physical processes drive galaxy evolution. Although we know the parts of galaxies, it isn't clear how they fit together and interact over time.

For example, observations show that properties of central supermassive black holes correlate with those of galactic bulges, but how this relationship develops remains hazy. We might gain a better understanding of this correlation as we discover more about how and when central black holes and galactic bulges get most of their mass.

Jay Gallagher

Professor of astronomy at the University of Wisconsin-Madison and editor-in-chief of *The Astronomical Journal*

Jumping down the galaxy-mass scale to the least massive dwarf elliptical galaxies exposes more problems. Models where galaxies form from "cold dark matter" — slow moving, unseen particles that make up most of the universe's missing mass — predict hoards of small galaxies. Despite large increases in the numbers of such objects, we still are coming up short. Why? Are some small galaxies simply dark and thus invisible, or is something else wrong?

We can expect progress from new classes of multi-wavelength observations combined with increasingly sophisticated theory. On the ground, 8- to 10-meter optical/infrared telescopes will continue to decode the inner workings of nearby galaxies. And a variety of enhanced radio capabilities will track how gas behaves and detect light from energetic particles.

There also will be sensitivity jumps in the era of 30- to 40-meter optical telescopes, the James Webb Space Telescope, and the Square Kilometre Array radio observatory. In a decade we will better know where our problems with galaxies lie.

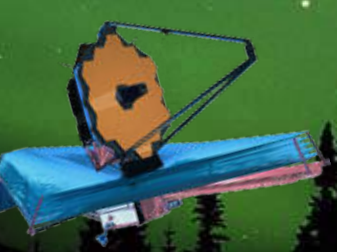


Photo courtesy Jay Gallagher

A DAY IN THE LIFE OF ...

Jason Cowan/UK ATC/ROE

Annette Ferguson

Associate professor of astronomy at the University of Edinburgh in Scotland

8:30 A.M. An hour of quiet time at home to respond to e-mails and browse the latest astrophysics preprints.

10 A.M. Devote time to those nebulous — and occasionally unenticing — administrative tasks: dealing with the financial issues of research grants, writing reports based on committee work, or conducting peer review of proposals or papers.

11 A.M. Look over lecture notes and make sure I can do all necessary derivations and can field questions about the material.

12 P.M. Lecture third-year astronomy majors in a course called "Astrophysics," covering topics like the Milky Way, external galaxies, stellar dynamics, active galactic nuclei, and cosmology.

2 P.M. Switch into research mode. Thanks to funding from the European Commission, I lead a research group of six postdoctoral fellows and Ph.D. students. I meet with them individually or in groups to discuss progress and problems. Any remaining time gets spent on my own research — analyzing data, writing publications, or preparing proposals for new observations or research funding.

4 P.M. Attend the weekly Edinburgh Astrophysics seminar where professional astronomers from throughout Europe (and sometimes from North America) visit our institute and tell us about their latest research.

Photos: NASA (James Webb Space Telescope); Jean Chiasson (green aurora); NASA/ESA/G. Bacon/STScI (brown exoplanet)

Geoff **Marcy**

Professor of astronomy at the University of California at Berkeley and exoplanet hunter

Volker Steger/UC-Berkeley

How did you get into the search for exoplanets?

In 1984, when I was 29 years old, I had just received my Ph.D. in astronomy, but I had no clue what sort of research to do. As a young astronomer, you are supposed to dream up innovative research projects that no one else has done. Unable to think of a good project, I became distressed that my career as an astronomer might be over. One morning, I was pondering my fate when it hit me that I should go for broke and hunt for planets.

I decided to use the Mount Wilson 100-inch telescope to measure Doppler shifts of stars to detect their wobble due to orbiting planets. I didn't find any for 11 years.

Tell us about your first exoplanet discovery.

In December 1995, my postdoctoral fellow Paul Butler and I saw a hint of a wobble in the star 47 Ursae Majoris that could be caused by a planet yanking on it. On the 30th, Paul phoned me at home and said, "Geoff, get over here." When I arrived at UC-Berkeley, I saw on the computer screen the unmistakable Doppler wobble of the star 70 Virginis caused by its 8 Jupiter-mass planet. We had bagged our first planet.

What's going to blow the lid off exoplanet searches?

NASA's Kepler Mission should begin taking data by mid-2009. It will detect earthlike planets for the first time by hunting for periodic dimming caused by planets crossing in front of 100,000 stars in the constellations Lyra and Cygnus. Kepler will provide humanity with its first clue as to whether other Earths are common in the universe.

One morning, I was pondering my fate when it hit me that I should **go for broke and hunt for planets.**

Where do you see yourself 10 years from now?

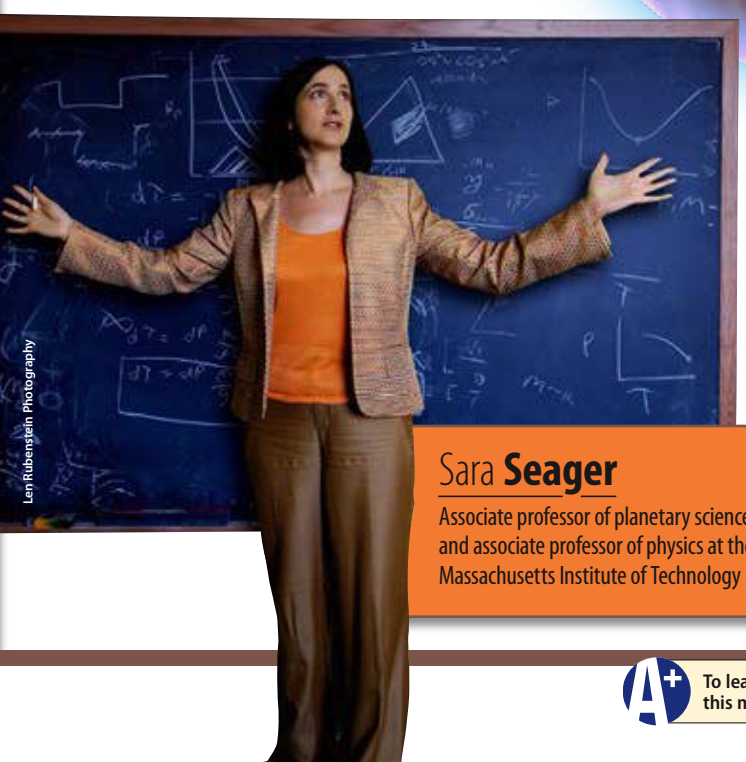
I love teaching astronomy, and I love researching exoplanets with my colleagues. I'm also dying to help NASA's Space Interferometry Mission and the proposed Terrestrial Planet Finder take the first pictures of other Earths around stars in our solar neighborhood and hunt for life on them.

What do you do in your spare time?

I'm a totally out-of-control tennis player. I play every day, take lessons, and hang out with the UC-Berkeley tennis team, hoping that the players' magic will rub off on me.

Astro**fascinations**

What fascinates you most about exoplanet atmospheres?



Len Rubenstein Photography

Sara **Seager**

Associate professor of planetary science and associate professor of physics at the Massachusetts Institute of Technology

Atmospheres are the "windows" to signs of life on a planet. If viewed from afar, Earth's atmosphere contains "spectral" fingerprints of oxygen, ozone, water, and other gases.

Oxygen in the atmosphere comes from life — plants and photosynthetic bacteria. We call oxygen a biosignature because under almost all situations we can think of, only life can fill the atmosphere with oxygen. Ozone is created from oxygen via the Sun's ultraviolet rays and is also a good biosignature.

Water is one of the easiest gases to detect remotely. All life on Earth requires liquid water, so the conventional sign of habitability is a planet with liquid water oceans. Because it is so hard to detect oceans remotely on exoplanets, our best bet is to find signs of water vapor in a planet's atmosphere. We're working hard to understand other gases that could be biosignatures.

It is amazing that we can already measure atmospheres of exoplanets. With current technology (the Hubble and Spitzer space telescopes) we observe hot Jupiters — planets extremely close to and intensely heated by their parent stars. We are eagerly trying to detect smaller, cooler planets more reminiscent of Earth. Luckily, we won't have to wait until the extremely difficult discovery of true Earth twins. Big Earths transiting very close to small stars are much easier to find and study. We're looking for atmospheres with huge quantities of some unexpected gas that might be, with further study, attributed to life.

To learn more about the people featured this month, visit www.Astronomy.com/toc.

The King's stellar cauldron

The vast emission nebula IC 1396 spans nearly 3° in the rich Milky Way star fields of Cepheus the King. This star-forming region lies more than 2,000 light-years from Earth and spans at least 200 light-years. The section seen here measures 20 light-years across. The gas clouds glow as they absorb ultraviolet light from newborn stars and reradiate it at red and infrared wavelengths. Dark dust blocks much of this light from view. IC 1396 contains enough material to form thousands of stars. This false-color image represents a tiny part of the INT/WFC Photometric H-alpha Survey of the northern galactic plane, taken with the 2.5-meter Isaac Newton Telescope in the Canary Islands.

Nick Wright (UCL)/The IPHAS collaboration

A Grandparent's cosmic adventure

As a parent, I have thought many times, "I hope my kids have learned as much from me as I have from them." As a grandparent, I continue to thrill at the physical, emotional, social, and intellectual growth of the next generation. The last holiday season was very special because a Christmas telescope was at the core of our adventures.

The Meade DS 2000 was my gift to my 10-year-old grandson Cole. Our first outing together was New Year's Eve. Starting just after sunset, we visited the Moon, Venus, and beyond. And we brought in the New Year with the Quadrantid meteor shower.

On January 2, after several visits to "other worlds," we decided to camp out in the bed of my pickup truck under the eastern Kansas prairie sky. Early ground fog added to the excitement and magic of the brilliant heavenly display.

Grandparenting is an opportunity to buy and share the toys we couldn't afford as kids. A telescope has proved to be a wonderful investment for our family. I encourage any parent or grandparent to consider astronomy. Youth sports are great, given the appropriate time and level of competition. However, sharing these cosmic adventures is every bit as challenging, exciting, and memorable while providing unlimited growth of the imagination and curiosity.

Joe Bournonville

Cole Kramer looks through his new telescope. The gift from his grandfather enabled them to explore the New Year's Eve sky.

This past holiday, we created memories that will last a lifetime and beyond. Just as my dad pointed out the Big Dipper, North Star, and aurora borealis to me, I have passed on the tradition to my kids and grandkids.

Thank you, *Astronomy*, for providing the framework for our cosmic adventures. My first copy of your magazine was borrowed. However, we have now subscribed and look forward to years of enjoyment. **— Joe Bournonville,** Arcadia, Kansas

Viewing rings

Because Uranus' year is approximately 84 Earth years, successive equinoxes — one with left-pointing rings and one with right-pointing rings — are about 42 Earth years apart. From 1789 (William Herschel's observations) to 1995 (the Hubble Space Telescope era) is 206 Earth years, or about five uranian equinox sets. If Hubble today sees left-pointing rings (page 16, January 2009), Herschel would have seen right-pointing rings in 1789.

It's a shame Herschel didn't continue observing Uranus at least through about 1810, at which time he might have seen the rings as a circle surrounding the planet (as shown in the Voyager image on page 17, January 2009). I'm surprised he didn't continue to make observations annually, at opposition, over as many years as possible. He might have confirmed the rings and deduced the odd tilt. Maybe he found seemingly more interesting projects. **— Richard L. Cole,** Ann Arbor, Michigan

Another piece of pi

Regarding Bob Berman's "A piece of π" (November 2008), I know of another interesting use of π. Although it is just a coincidence, I find π useful in a context far different from circumferences: The number of seconds in a year is very close to $\pi \times 10^7$ (that is, pi times 10 million). The accurate answer is 31,536,000 in most years and 31,622,400 in leap years, plus an occasional leap second. The approximation is almost always good enough for astronomical purposes.

— Jay Pasachoff, Pasadena, California

The Moon, not Mars

The Planetary Society directors think the United States should do manned missions to Mars and not manned missions to the Moon. I disagree, and here's why:

1. Going to the Moon is cheaper.

2. We can build a permanent base on the Moon. On Mars this is questionable.

3. One can view Earth from the Moon easier than from Mars. These observations may be quite valuable.

4. The Moon has less mass, and thus it's easier to escape the Moon's gravity.

5. It requires less time in space to get there, and space travelers would be safer.

6. The Moon is closer, so its resources can be exploited easier than those of Mars.

7. Because the Moon has no atmosphere, it is a good astronomy platform.

— Gary Vardon, West Valley City, Utah

Correction

In the sidebar box on page 58 of "How Johannes Kepler revolutionized astronomy" (January 2009), Kepler's Third Law is listed incorrectly. The form shown is only applicable if the mass of the exosolar system's star is equal to the Sun. If the star has a different mass, the equation takes the form $p^2 = (4\pi^2/GM_{star})\, a^3$, where G is a constant called the gravitational constant and M_{star} is the mass of the star in units of solar masses. **— *Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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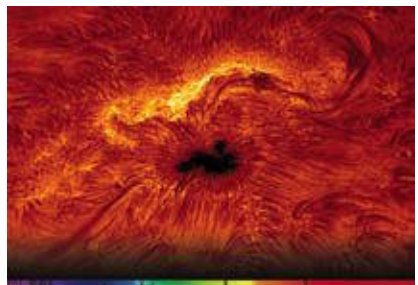

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Strange Universe

by Bob Berman

Light fantastic

After 90 years, a key tool used to understand the universe is still a strange concept.

History's most famous eclipse was the one that made Albert Einstein a household name. It happened 90 years ago this month and involved a strange blend of altered light, a genius mind, and maybe some faked science.

We've all heard the story. General relativity said space can warp, so a star near the Sun's edge would seem to jump outward, its light-path bent like a rubber band. If Einstein was correct, the star should appear in a new, wrong place.

Astronomer Arthur Eddington planned to confirm this with the May 29, 1919, African eclipse, with the Sun in Taurus among the Hyades stars. Afterward he said he detected the tiny predicted star-shifts of about an arcsecond. Einstein became an instant celebrity.

But hold on. Those 5th-magnitude stars were buried in the bright solar corona. It was daytime; the seeing was turbulent. Other astronomers were skeptical: "You made extraordinarily precise measurements with a 4-inch scope? In blurry air? No way!" Was Eddington influenced by his own pro-Einstein bias? Or the promise of fame if his results were sensational? Did this Quaker, pacifist, and all-around nice guy cook the data? Or was he just darn good?

It's still debated, but it hardly matters. As they say in football, "The ruling on the field stands." Einstein was deemed a genius, and light was declared bendable. Because both were later confirmed anyway, we simply sigh and leave the dubious 1919 eclipse alone.

Everything keeps coming back to the subject of light. It's our only tool for probing the universe. But it's as strange and enigmatic now as it was back then.

We can think of light as a tiny bullet — a ghostly photon that, unlike everything else, must always move. If it stops, it ceases to exist. Or we can picture it as two symbiotic waves traveling together perpendicularly — a magnetic and an electrical pulse. Its speed is amazing. You know the figure: 186,282.4 miles per second. If you somehow prefer meters per second, it's 299,792,458. Very fast. Bounce light between two mirrors in Hollywood and Brooklyn (you'd need a third mirror in the sky to negotiate Earth's curve) and it would make 60 coast-to-coast trips in a second.

Can you picture that? I can, sort of. Now imagine photons continuing on for a whole year, and you've grasped a light-year. The star Vega is 25 light-years away.

Light independently ignores everything else and zooms along special paths through space-time.

So the Vega we see is a light-image that left the star in 1984. Any Vegans now watching Earth through a super-telescope while munching on bean sprouts would view each of us as we were in 1984, too. Very Orwellian.

Instead of using light, try expressing Vega's distance with astrophysics' favorite yardstick, the parsec. Vega is 7.76 parsecs away. What does that do for you? Nothing. It doesn't help anyone comprehend vast distances. The parsec should be illegal.

Light travels a foot in a nanosecond, a billionth of a second. You view the past by as many nanoseconds as there are feet separating you from the object seen. You observe your friend across the room, 20 feet away, not as she is now, but as she was when she was 20 billionths of a second younger. It matters. When your GPS gets time signals from satellites 12,600 miles (20,200 kilometers) up, the time from each is delayed and therefore wrong by as much as one-tenth of a second, letting the gadget figure out your distance from each one. It then triangulates your position — all from the reliable speed of light.

Light moves more slowly through water — 140,000 miles per second (225,000,000 m/s) — and glass — 124,000 miles per second (200,000,000 m/s). But photons don't truly slow down. Rather, each hits an atom, gets absorbed and re-emitted, and a new photon continues on. The process takes a tiny bit of time, hence the delay. The lights and colors we see through windows are different photons from the ones that first struck the glass.

Cool, but it is light's constancy that's maximally amazing. Most folks still don't truly get this. Imagine if you tried to signal an ultrafast rocket moving at almost light-speed. Say you flashed a laser at it after it sped away. You'd watch the light very slowly gain on the rocket because they're both heading in the same direction at around the same speed. Logic tells us the light should hit the departing ship very slowly because it had to catch up. But in truth, the crew would measure the incoming light whizzing in at the same superfast speed as always, as if the rocket were standing still.

Makes sense? Not really. Light has its own reality. It independently ignores everything else and zooms along special paths through space-time, called null geodesics. This magical realm — which includes curved space, mutating time, and distances that change depending on circumstance — is the weird portal the world entered 90 years ago.

Eddington notwithstanding, you can't make this stuff up.

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Secret Sky

by Stephen James O'Meara

A volcanic sunset

From your backyard, see the atmospheric effects of a volcano eruption.

Doug Zubenel captured Earth's shadow in the west after sunset August 25, 2008, from Kill Creek Park in Johnson County, Kansas. During this unusual sight, which Zubenel later discovered was due to volcanic aerosols, a clean line separated the golden-yellow of the sunlit aerosol layer in the west from Earth's shadow above it. Several minutes later, that straight boundary dropped lower, until it "set" on the distant tree line.

If you live in the Northern Hemisphere, you may have noticed that the skies at dusk and dawn have been unusually striking since August 2008. Twilight's once soft cerulean glow is now more luminous, as if glazed with frost. The consoling orange band that used to hug the horizon about 15 minutes after sunset has been replaced with a diffuse, incendiary glow that gives way to robust hues of yellow, rose, and purple higher up. Deep twilight colors have become warmer and more intense.

You also may have noticed crepuscular rays (the rosy fingers of dawn and dusk) now appear more frequently as cloud shadows scratch their long blue fingers across twilight's pink sky — sometimes all the way to the opposite side of the sky. These strange twilight effects also arrive earlier in the east before sunrise and linger longer in the west after sunset, causing high points on the opposing landscape (like mountain peaks or trees) to reflect a brilliant red light, especially in photos. What's going on?

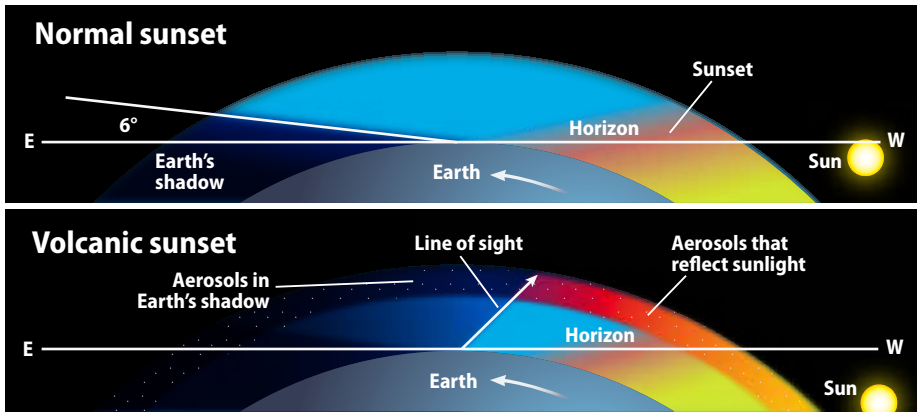
It's a blast!

On August 7, 2008, Kasatochi, a small 1,000-foot-high (300 meters) island volcano in the Aleutians in southwestern Alaska, exploded without warning. The eruption sent ash and other volcanic particles 8.5 miles (13.7 kilometers) high. Preliminary reports reveal the volcano also injected about 1.5 million tons of sulfur dioxide into the stratosphere. The sulfur dioxide greenhouse gas should interest you as a skygazer.

When a powerful volcanic blast thrusts sulfur dioxide into the stratosphere, the gas first passes through Earth's cold lower atmosphere. As the gas rushes upward, it reacts with water droplets and sunlight to form aerosols of sulfuric acid, which condense rapidly in the stratosphere.

Unlike ash, which soon falls back to Earth, sulfuric acid aerosols stay in the stratosphere for years. (Roughly one-third of the aerosols settle out each year.) This contaminant effectively reflects, scatters, and absorbs sunlight. To the visual observer, this means an overall reddening of the sky.

The reddening is especially enhanced during twilight because of the longer path light must take through the atmosphere to reach our eyes. As stratospheric winds disperse the aerosols, more and more people see the effects. To date, people are



Earth's shadow normally appears as a dark band low in the east after sunset. As Earth rotates, that band rises until it reaches an altitude of about 6°, then blends into the darkening sky (top). But when volcanic aerosols fog up the stratosphere, it's possible for us to see Earth's shadow impose itself on the glowing aerosol layer in the west after sunset (bottom). As Earth rotates, the dark shadow seems to "push" the aerosol glow down toward the western horizon until the shadow "snuffs" it out.

reporting the spooky effects from Finland to Hawaii. Because Kasatochi is a northern polar volcano, it is unlikely the effects will reach the Southern Hemisphere.

Light and shadow

Long-time sky photographer Doug Zubenel of Johnson County, Kansas, has been monitoring the Kasatochi color show since August 22. He has supplied me with a detailed report worthy of note. Perhaps you'll recognize some of the strange twilight phenomena he describes.

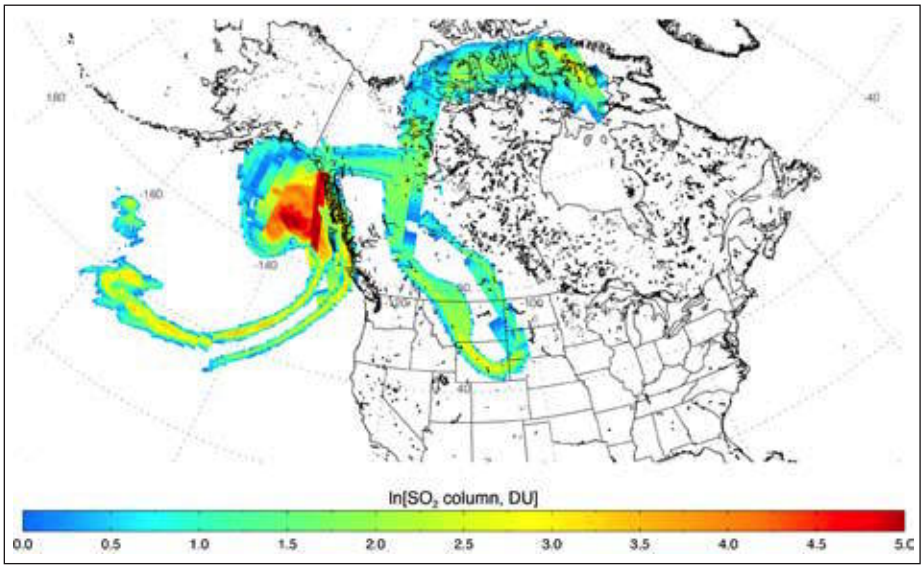
On August 22, Zubenel traveled to one of his favorite observing sites and saw something puzzling. Around the time of sunset, some mysterious clouds — aligned in rippling bands and oriented southwest to northeast — polluted the northwestern sky to an altitude of about 60°. "The longer I observed these clouds," Zubenel recalls, "the more it became clear that they were either not moving or moving very, very slowly."

As the twilight deepened, Zubenel saw a golden-yellow light begin to fill the western sky to an altitude of 50°. The light, which was centered on the Sun's position, eventually faded, "but it lasted far longer than an ordinary twilight would at this time of day and year," he notes.

Zubenel suspected volcanic aerosols, although he did not learn about Kasatochi's eruption until August 25. That night, while setting up his camera at Kill Creek Park in Kansas, he documented another amazing effect. As the color show unfolded, the glow's upper edge appeared unusually straight and parallel to the horizon, cleanly dividing the luminous aerosol cloud in the west from the darker sky above it.

Several minutes later, Zubenel watched that straight boundary drop lower until it "set" on the distant tree line. "Somehow, I intuitively knew what I had just witnessed," he says, "even though I had never seen such a phenomenon."

Zubenel shared his observations and photographs with Les Cowley at Atmospheric Optics (www.atoptics.co.uk). After looking at the geometry of the situation, Cowley confirmed Zubenel had seen Earth's shadow in the west after sunset! We commonly see Earth's shadow rising as a dark band in the east after sunset. As Earth rotates, that band rises until it reaches an altitude of about 6°, when it blends into the darkening sky background and fades from view.



NASA OMI image courtesy S. Carn/Joint Center for Earth Systems Technology/UMBC

Kasatochi's eruption caused a gas cloud, as seen from this NASA Aura satellite image, that by August 12, 2008, had moved in a large counterclockwise loop over the Pacific Ocean, while winds sent streamers eastward across the United States and Canada. By November, the cloud had pretty much veiled the Northern Hemisphere in a weak stratospheric fog.

But when volcanic ash fogs up the stratosphere, we can see Earth's shadow against the glowing aerosol layer in the west after sunset, as shown in the diagrams on page 18. As Earth rotates, more and more of the thin aersol layer falls into Earth's shadow, which seems to "push" the sunlit portion lower toward the western horizon until the shadow "snuffs" it out.

How long?

How long will the Kasatochi twilight displays last? According to the July 2008 *Bulletin* of the Global Volcanism Network, Kasatochi's stratospheric aerosol cloud was one of the largest since the 1991 Mount Pinatubo eruption in the Philippines. So abnormal twilights may be with us for some time. Note, however, that while the intensity of the displays starts out strong, it generally softens as stratospheric winds disperse the gases.

Crepuscular rays — rosy fingers of light that radiate up from the sunrise or sunset point on the horizon — can result from Kasatochi aerosols in the twilight sky. A display of faint anticrepuscular rays converging on the antisolar point just below the opposing horizon can also occur. Doug Zubenel captured this image October 10, 2008, from Johnson County, Kansas.

Zubenel notes that the Kasatochi sky show generally begins just a few minutes after sunset. Look for a large dome of yellow-ocher light whose upper portions turn rose, then purple, as twilight deepens. "Ultimately," he says, "the purple and rose colors fade into the encroaching night, while the yellow deepens to orange lower down. Some 30 minutes after sunset, all that's left is a reddish-orange horizon band that turns red before it fades from view."

The colors were still strong at times in early February, though somewhat muted. By the time you read this article, these effects may have weakened further. But Kasatochi is not the only sulfur-rich volcano that has come to life in recent years.

For instance, on November 3, 2008, a volcanic eruption in the Afar region of Ethiopia expelled a large sulfur dioxide cloud (100,000 tons) that spread across the Arabian Peninsula and northern India in just 2 days. And who knows what sulfur-rich volcanic action tomorrow will bring? What's important is that you keep an eye on the sky and be aware. As always, send your reports to me at someara@interpac.net.

NASA on TV NASA's 30-minute video show, NASA 360, finished its first season in January. You can download the video podcast of the latest program at www.nasa.gov/nasa360.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

Rare pair. This Hubble Space Telescope image shows a planetary nebula within an open star cluster. Such pairings are uncommon. NASA/ESA/Hubble Heritage Team (STScI/AURA)

Long-lived star cluster harbors an aged nebula

The Hubble Space Telescope has captured the image of a celestial odd couple: the nebulous remnant of an old star nestled within a type of star cluster that usually disbands before its members reach old age. The Space Telescope Science Institute in Baltimore released the portrait January 15.

The image features planetary nebula NGC 2818. It formed as an aging star ran low on fuel and began to cast off its outer layers. The nebula sits within open star cluster NGC 2818A — a relatively young group of suns loosely bound by gravity.

Most open clusters disperse into the void within a few hundred million years. But it usually takes longer than that for a planetary nebula to form. In this case, NGC 2818A is an unusually long-lasting cluster at an estimated 1 billion years old. — **DANIEL PENDICK**

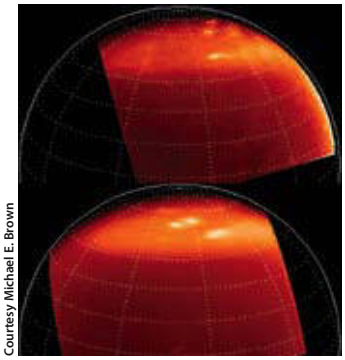
22 Young Moon boasted strong magnetic field

24 Spitzer spots more ingredients of earthlike planets

25 Simulations hint at massive-star formation

26 New view of the Milky Way

28 X-ray satellite spots magnetar



Courtesy Michael E. Brown

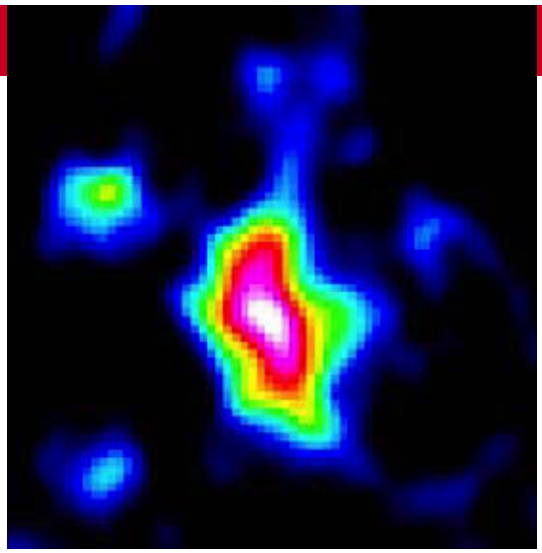
Cloudy weather. The Cassini Orbiter's Visible and Infrared Mapping Spectrometer imaged clouds (white patches) in Titan's northern polar region April 13, 2007.

Spring brings cloudy skies to Titan

Astronomers have discovered huge, streaky clouds of methane rising from lakes on Titan as the saturnian moon's northern hemisphere emerges from the decade-long winter season. Caltech planetary scientist Michael Brown and colleagues reported their findings January 3 in *Geophysical Research Letters*.

The clouds have appeared sporadically in images captured by the Cassini Orbiter from 2004 to 2007. They rise to heights up to 19 miles (30 kilometers) and trail for hundreds of miles. Brown says they resemble cumulus clouds on Earth, which form as moisture rises and condenses into vapor particles. Thunderstorms develop from Earth's cumulus clouds.

As spring starts in Titan's northern hemisphere in August, Brown predicts cloud activity could "go crazy" as solar heating of lakes intensifies. It's possible the clouds will unleash methane rainstorms. This would represent a key link between the moon's surface and atmosphere. — **D. P.**



Middleweight. The Very Large Array radio telescope imaged gas in this galaxy, J1148+5251, as it existed when the universe was 870 million years old. At this time, galaxies' central black holes were much more massive relative to their central bulges of gas and stars. NRAO/AUI/NSF

Clues help crack chicken-and-egg galactic mystery

Did galaxies appear in the early universe and then incubate massive black holes at their centers — or was it the other way around? "It looks like the black holes came first," says astronomer Chris Carilli of the National Radio Astronomy Observatory. "The evidence is piling up."

Carilli is one of an international team of researchers studying the roots of galaxy evolution in the early universe. He described the group's latest findings January 7 at a meeting of the American Astronomical Society in Long Beach, California.

Previous research has shown that the central bulges of large galaxies are about 500 times more massive than their central black holes. This implies some kind of connection between the growth of galaxies and their black holes. "The big question has been whether one grows before the other or if they grow together, maintaining their mass ratio throughout the entire process," says Caltech astronomer Dominik Riechers.

Researchers used the Very Large Array radio telescope near Socorro, New Mexico, and the Plateau de Bure Interferometer in France to observe four galaxies as they were in the first 1 to 2 billion years of cosmic history. The bulge-to-black-hole ratio in these young galaxies is more like 30 or 40 to 1 instead of 500 to 1.

"The implication is that the black holes started growing first," says Fabian Walter of the Max Planck Institute for Astronomy in Heidelberg, Germany. New and larger radio telescopes will allow astronomers to study additional distant galaxies and see if they show the same trend. — **D. P.**

QUICK TAKES

NASA HAILS TO THE CHIEF

Astronauts driving a prototype 12-wheeled lunar rover occupied the tail end of President Barack Obama's inaugural parade January 20.

HIGH-FLYING BALLOON

NASA tested a new balloon December 28 at the South Pole. It can loft instruments more than 100,000 feet (30 kilometers) for 100 days or longer.

ROUND-THE-WORLD TOUR

Russia will launch its last space tourist to the International Space Station in fall 2009. Russian space agency director Anatoly Perminov disclosed the decision January 22 in a press interview.

GAMMA-RAY PULSARS

NASA's Fermi Gamma-ray Space Telescope has discovered 12 pulsars visible only in gamma rays, scientists reported January 6.

CATALINA BEATS ITS BEST

The University of Arizona's Catalina Sky Survey discovered 565 near-Earth asteroids in 2008, beating its 2007 tally of 460, the university reported January 9.

WORLD NEWS

On January 14, researchers reported that ground-based telescopes had for the first time distinguished the glow of an extrasolar planet from the glaring light of its host star.

DARK NO MORE

NASA reported January 16 that its Mini-SAR radar on India's Chandrayaan-1 spacecraft captured the first images inside permanently shadowed craters near the Moon's poles.

BUT IT'S A DRY HEAT

Extrasolar planet HD 80606b's temperature rose from 980° to 2240° Fahrenheit in just 6 hours as it swung close to its host star, researchers reported January 29 in *Nature*.

ASTRONAUTS: LESS HIP

After 4 to 6 months in zero gravity on the space station, astronauts' hipbone strength decreased 14 percent. University of California researchers reported the finding January 26.

GO GOSAT

On January 23, the Japan Aerospace Exploration Agency launched its Greenhouse Gases Observing Satellite (GOSAT). The craft measures atmosphere-warming gases.

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Lunar field work. **New clues gleaned from this ancient lunar rock suggest the Moon once had a strong magnetic dynamo. This sample is about 2 inches (5 centimeters) long.** Courtesy Ian Garrick-Bethell

Young Moon boasted strong magnetic field

A new analysis of an ancient rock sample collected by Apollo astronauts suggests the early Moon had a spinning liquid iron core with a strong magnetic dynamo just like Earth's. MIT graduate student Ian Garrick-Bethell and colleagues reported the new evidence January 16 in *Science*.

The researchers found the imprint of the Moon's ancient magnetic field in a 4.2-billion-year-old rock collected by Apollo 17's Harrison Schmidt during the final lunar landing in 1972. "It is one of the oldest and most pristine samples known," Garrick-Bethell says.

Scientists have found magnetic imprints in many Moon rocks but aren't all agreed on what created the patterns. One possibility is that magnetic fields generated by meteorite impacts left the imprints. But the Apollo 17 sample shows no signs of a meteorite impact.

The rock's pristine condition and new and more precise measurements of its magnetic record enabled Garrick-Bethell and his colleagues to rule out the meteorite theory. That helps strengthen the case for a long-lasting and relatively strong lunar magnetic field. "It favors the dynamo theory," Garrick-Bethell says.

The new measurements suggest the Moon's field was once 1⁄50 as strong as Earth's is today and persisted for at least millions of years. — **D. P.**

Astronomers CT-scan the cosmos

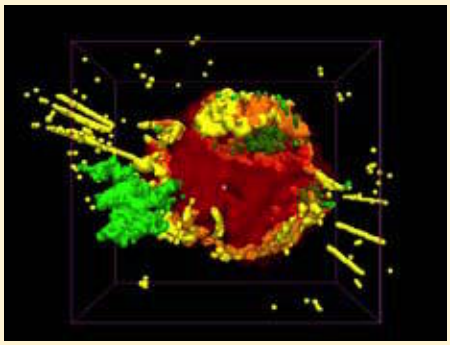
Call it a prescription for better science: Astronomers are now exploring outer space with the same technology doctors use to explore the inner spaces of the body. The key advance is powerful visualization software that allows astronomers to create 3-D representations, or "models," of complex structures. Deeper looks at interstellar gas clouds and supernova remnants are already producing fresh insights.

At January's American Astronomical Society meeting in Long Beach, California, MIT astronomer Tracey DeLaney unveiled just one example of what medical visualization is revealing about the celestial sphere. DeLaney's study focused on the Cassiopeia A (Cas A) supernova remnant, the expanding cloud of debris from a star that exploded about three centuries ago.

DeLaney and her colleagues used a program called *3D Slicer* to recreate Cas A based on data from NASA's Spitzer Space Telescope, the Chandra X-ray Observatory, and ground-based instruments. Researchers at Harvard's Brigham and Women's Hospital originally created *3D Slicer*. It allows doctors to transform data from medical imaging techniques, such as computerized tomography (CT) scanning, into detailed visualizations.

Like the cyberworlds in video games, DeLaney's visualization of Cas A is a mathematical representation of the real object. That means it's possible to interact with the model — say, by zooming in on a particular feature or rotating it to get a different perspective.

Using *3D Slicer*, DeLaney uncovered hidden features of the supernova remnant. These included a spherical blast shell formed from the outer layers of the exploding star and a disk-shaped structure that evolved from the star's core. High-speed plumes of debris shoot out from the disk.



Inside story. **Researchers created this 3-D model of the supernova remnant Cassiopeia A using technology originally developed to explore the human body.** NASA/CXC/MIT/T.DeLaney et al.

3D Slicer and similar tools have found their way into astronomy largely because of the efforts of the Astronomical Medicine Project at Harvard University's Initiative in Innovative Computing (IIC). The project works to adapt medical visualization tools to the needs of astronomical research.

Astronomical medicine allows researchers to tap a powerful tool they already had — the human visual system. Our brains excel at quickly recognizing patterns. Seeing celestial objects in a new way, followed by detailed scientific analysis, promises to lead astronomers to greater understanding.

Astronomers often find themselves awash in complex data that takes weeks or months to slog through. Astronomical medicine offers a potentially faster route to insight. Says IIC's founding director, Harvard astronomer Alyssa Goodman, "Astronomers may come to see these new tools as a necessity, rather than an extravagant curiosity, to keep up with the tsunami of new data." — **D. P.**

Check out 3-D animations of celestial objects made with medical imaging tools here: astromed.iic.harvard.edu/movies.

Jupiter-like worlds bulk up fast

Giant gas planets like Jupiter probably form in less than 5 million years, Thayne Currie of the Harvard-Smithsonian Center for Astrophysics and colleagues reported January 5 at the American Astronomical Society meeting in Long Beach, California.

The researchers examined young solar systems in the star cluster NGC 2362, which is known to be about 5 million years old. They found that all stars in the cluster with the mass of our Sun or greater had no planet-forming disks of dust and gas.

Such "protoplanetary disks" provide the raw material to build planets like Jupiter. This suggests that Sun-like stars may no longer have the stuff to build gas giants past 5 million years. If gas giants don't form by then, they may not form at all. — **D. P.**

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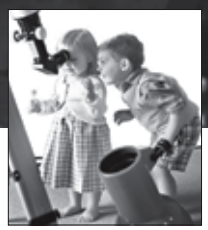

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8mm Ethos – 1.25"/2", 100° **585**
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The Astro-Tech Voyager – "a really sweet grab-and-go."

A recent review said that the $299 **Astro-Tech Voyager** altazimuth mount was "unusually stable for its size and weight" and that it was packed with "lots of first-class engineering" that made it "a really sweet grab-and-go setup that's ideal for viewing day or night."

The review praised the Voyager's "smooth slow motion controls . . . Couple them with the Voyager's stability, and it was a pleasure viewing at magnifications approaching 200x – something I can't say for most altazimuth mounts that you have to push by hand."

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Dark Moon rising New findings reported January 6 suggest ash from a volcanic eruption may explain the Moon's strangely dark appearance May 18, 1761.

Another one bites the dust. In this artist's conception, asteroids as large as 125 miles (200 kilometers) across meet their doom in a star's powerful gravitational field. NASA/JPL-Caltech

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Spitzer spots more ingredients of earthlike planets

Spitzer Space Telescope observations of shredded asteroids in six other star systems suggests the raw ingredients of rocky planets may be common in the universe. "If you ground up our asteroids and rocky planets, you would get the same type of dust we are seeing in these star systems," says UCLA's Michael Jura, who reported the finding January 5 at the American Astronomical Society meeting in Long Beach, California. "This tells us that the stars have asteroids like ours and therefore could also have rocky planets."

Planets and asteroids coalesce inside disks of dust and gas swirling around young suns. Initially, dust grains stick together to form slightly larger bodies. These may grow larger still and then attract enough material to form planets. The leftover debris remains as cool interplanetary dust and asteroids.

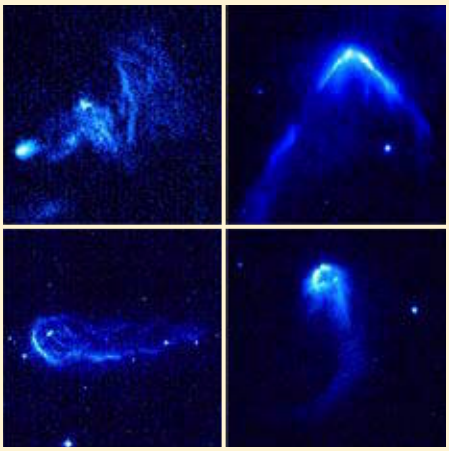
Spitzer probed six solar systems in which the central stars had evolved into dense remnants called white dwarfs. If asteroids drift too close, the gravitational tides around the white dwarfs shred them to pieces. A similar fate befell Comet Shoemaker Levy 9 in 1994, when Jupiter's gravity tore it up into 21 fragments.

The warm dust cloud around such "polluted white dwarfs" glows in infrared. This allows Spitzer's instruments to determine the dust's chemical composition.

Previous Spitzer research identified two polluted white dwarfs. The latest findings bring the total count to eight. "Now, we've got a bigger sample of these polluted white dwarfs," Jura says, "so we know these types of events are not extremely rare."

In all eight systems observed to date, Spitzer found a glassy mineral in the dust grains similar to olivine, which is common in Earth rocks. Also, Spitzer found scant signs of carbon in the rocky debris — again, just like our solar system's carbon-poor planets and asteroids.

Jura and his colleagues detail their research on the shredded asteroid stars in a report slated for publication in *The Astronomical Journal*. — **D. P.**



NASA/ESA/R. Sahai (JPL)

Just plowing through. Like a ship through water, each of these "ballistic stellar interlopers" creates a bow shock through the interstellar medium of gas and dust.

Looking for one object, astronomers discover another

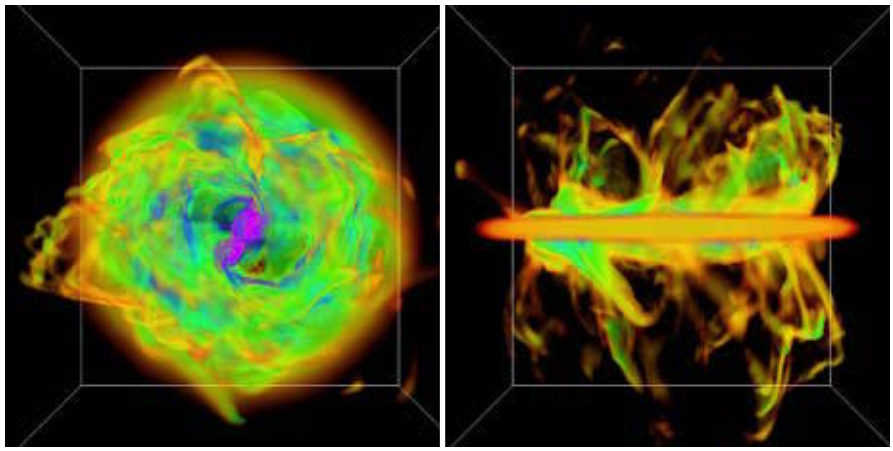
A group of astronomers pointed the Hubble Space Telescope toward what they thought were 38 stars on the verge of shedding their outer layers. As it turned out, 14 of those objects are actually runaway stars followed by wakes of dust and gas. The astronomers announced their findings January 7 at a meeting of the American Astronomical Society in Long Beach, California.

The 14 objects appear to be moving fast (more than 112,000 mph [180,000 km/h]) through the dense interstellar medium (ISM) — a mix of gas and dust permeating space. Each star emits a wind of gas and particles like the Sun's stellar wind, but stronger. The stellar wind then slams into the ISM, creating a bow shock. In each image, a bow shock leads the star and a tail of material trails.

The astronomers, led by Raghvendra Sahai of NASA's Jet Propulsion Laboratory in Pasadena, California, believe the stars are young — a few million years old — because of their strong stellar wind. They're also probably a few solar masses (more massive stars have lots of ionized gas around them).

Where did these objects come from? "The high-speed stars were likely kicked out of their homes, which were probably massive star clusters," Sahai says.

Follow-up studies are needed to find more of these objects and understand the stars and their environments. — **LIZ KRUESI**



Simulated stars. After 55,000 years of simulated evolution, two massive stars have formed. The left image shows the view from above; the right simulation presents the side view. Gas instabilities act as channels for accreting material to fall in and radiation to escape. Krumholz et al.

Simulations hint at massive-star formation

Astronomers have long wondered how the most massive stars form because they're so bright that their radiation pressure should push away the gas clouds that feed the star. New computer simulations, however, show that even with this radiation pressure, enough material falls into the protostar to form a massive star. The scientists, led by Mark Krumholz of the University of California at Santa Cruz, published their report January 15 in *Science Express*.

As material accretes onto a protostar, it heats up and emits radiation. This radiation pushes outward, fighting against gravity and the material collapsing into a star. The 3-D simulations showed that this push and pull creates instabilities. These instabilities act as channels for radiation to escape the growing star, while gas continues to fall as a result of gravity. "You can see fingers of gas falling in and radiation leaking out between those fingers of gas," says Krumholz.

The instabilities also lead to material clumping into multiple stars. In the simulations, multiple-star systems formed, mirroring what astronomers observe in our galaxy — many massive stars are in binary or triple star systems. — **L. K.**

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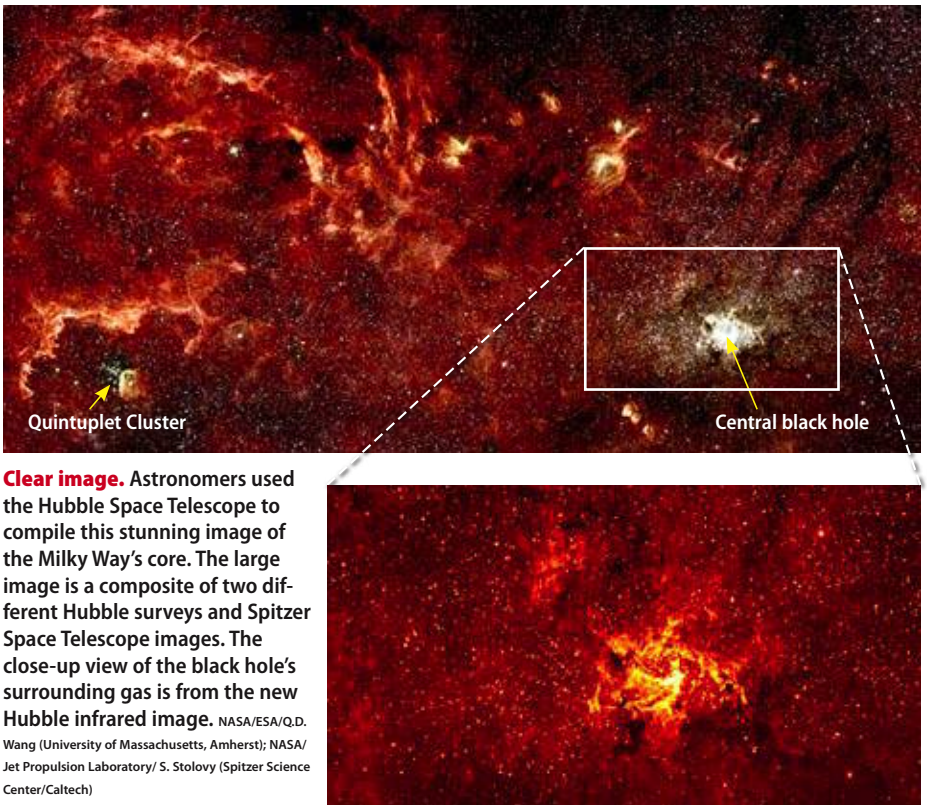
Made in Iran

Iran announced February 1 that it had launched its first home-built satellite. The nation is now one of nine with the capability to loft satellites.



Clear image. Astronomers used the Hubble Space Telescope to compile this stunning image of the Milky Way's core. The large image is a composite of two different Hubble surveys and Spitzer Space Telescope images. The close-up view of the black hole's surrounding gas is from the new Hubble infrared image. NASA/ESA/Q.D. Wang (University of Massachusetts, Amherst); NASA/ Jet Propulsion Laboratory/ S. Stolovy (Spitzer Science Center/Caltech)

New view of the Milky Way

Astronomers have captured the sharpest-ever infrared panoramic view of the Milky Way's center. The new image reveals previously unknown massive stars (even some in the midst of forming) and details about the structure of gas around our galaxy's supermassive black hole. The team, led by Q. Daniel Wang of the University of Massachusetts in Amherst, unveiled the image January 5 at a meeting of the American Astronomical Society in Long Beach, California.

By observing in the infrared, astronomers were able to pierce through our galaxy's dust to view the Milky Way's bubble structures and massive arcs. In the lower left, one can see the detailed structure of gas pillars, which intense radiation and wind from the Quintuplet Cluster sculpted. Also notice the swirling gas surrounding the central black hole.

The scientists used the Hubble Space Telescope to create this image, which spans some 300 light-years in width. They used 2,304 images and 144 Hubble orbits to create the composite. — **L. K.**

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Astronomers discover cosmic radio background

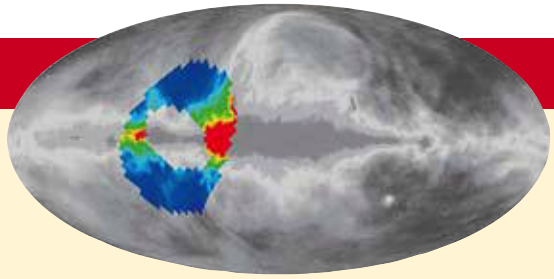
Using NASA's Absolute Radiometer for Cosmology, Astrophysics, and Diffuse Emission (ARCADE) balloon, astronomers stumbled upon an unexpected radio signal from beyond our galaxy. This radio static is some 6 times brighter than the combined radio emission of all the galaxies in the universe.

The scientists, led by Alan Kogut of NASA's Goddard Space Flight Center in Greenbelt, Maryland, announced their findings January 7 at a meeting of the American Astronomical Society in Long Beach, California.

ARCADE's initial science goal was to measure the heat signature of the first stars to form after the Big Bang. While the first stars can't be observed, they do heat up the surrounding gas and dust. The gas and dust then emit radiation in the infrared. This infrared signature is what ARCADE was looking for.

From 120,000 feet (36.6 kilometers) above eastern Texas, ARCADE observed about 7 to 8 percent of the sky. The researchers analyzed the signal and removed the foreground galactic signal. What they got was a far-too-strong radio signal.

They determined it can't be a result of the first stars — it's just too brilliant. They also ruled out known radio sources, and they're confident the signal is from outside the galaxy. They also said the signal is likely not associated with the cosmic microwave background. More experiments with finer resolution are needed to further analyze this signal. — **L. K.**



Radio static. NASA's Absolute Radiometer for Cosmology, Astrophysics, and Diffuse Emission (ARCADE) balloon scanned some 7 percent of the sky and found an odd radio signal emitting from outside our galaxy. The colored region shows the portion of the sky ARCADE surveyed. NASA/ARCADE

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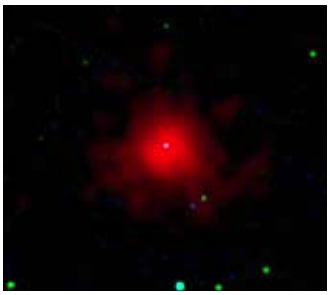
Double vision On February 6, NASA's twin STEREO satellites imaged both sides of the Sun simultaneously for the first time, thanks to the spacecrafts' 180° separation in space.



NASA/Swift/Stefan Immler

Emission glow. The Swift satellite observed GRB 080607, the second-brightest GRB yet detected, in X rays and optical light. In this image, red is X rays and blue and green are optical.

Astronomers use GRB to spy molecules

Astronomers have identified, for the first time, gas molecules in a gamma-ray burst (GRB) host galaxy. J. Xavier Prochaska of the University of California at Santa Cruz announced the team's findings January 6 at a meeting of the American Astronomical Society in Long Beach, California.

GRBs — the most luminous blasts in the universe — are the explosive deaths of massive stars. The powerful GRB 080607 was bright enough to enable astronomers to take a core sample of the gas and dust lying between Earth and the GRB some 11 billion light-years away. The astronomers studied the GRB's spectrum (the range of light emitted by the GRB), and they found molecular hydrogen and carbon monoxide. "Those are gases we associate with star-forming regions in our own galaxy," Prochaska says.

The team believes the GRB sits behind a large star-forming molecular cloud similar to those in the Milky Way. They think that in a brief amount of time (less than a few billion years) the host galaxy has become as chemically mature as the Milky Way, whereas it took our galaxy at least 8 billion years. While astronomers could decipher hundreds of different features in the spectra, many are still unidentified. **— L. K.**

X-ray satellite spots magnetar

Last summer, a highly magnetized star called a magnetar flared up again and emitted short radiation bursts. Magnetars are similar to neutron stars — the remnants of massive stars — but with magnetic fields some 1,000 times stronger. An international team of astronomers skewed the XMM-Newton satellite toward the object, one of only six of a type of magnetar called soft gamma repeaters (SGRs). For the first time, scientists were able to determine its rotation rate. The team, led by Paolo Esposito of the Istituto di Astrofisica Spaziale e Fisica Cosmica in Milan, published its results in the January 10 issue of T*he Astrophysical Journal Letters*.

Astronomers can determine a magnetar's rotation rate by how often they observe a flash. After SGR 1627–41 flared back to life, the team determined it rotates every 2.6 seconds.

Because astronomers know of only 14 magnetars, they still have many questions about these odd stellar objects, including how they can have such strong magnetic fields. **— L. K.**

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Cosmic weather predictor

Scientists using an underground detector reported that high-energy particles from space — called cosmic rays — are connected to weather in the upper atmosphere. When temperature increases, more cosmic rays arrive at the detector. This allows scientists to use cosmic ray records to figure out what was happening in the upper atmosphere. Their results will appear in a future issue of *Science*. — L. K.

Diamonds point to comet impact

Microscopic diamonds found at six locations in North America back the theory that a comet strike about 13,000 years ago wiped out mammoths and more than 30 other species, researchers reported January 2 in *Science*. Such tiny diamonds occur only in extreme pressures and temperatures, like those created by comet impacts. — L. K.

Robot scopes see super-Neptune

The automated telescope network HATNet found a planet just over Neptune's size orbiting a star some 120 light-years away, researchers announced January 16. The "super-Neptune," named HAT-P-11b, is only 4.7 times Earth's diameter. The extrasolar planet is the smallest found to date using the so-called transit method. When a planet passes in front of its star, it blocks some of the star's light. The amount of the dimming reveals the planet's size and orbit. — L. K.

25 years ago in *Astronomy*

May 1984

The May 1984 issue of *Astronomy* discussed the atmospheres of both our planet and neighboring planets and moons in "Atmospheres," by Edward J. Ciaccio.

Earth's atmosphere is necessary for life on our planet. It protects us from the Sun's radiation and distributes heat and precipitation. Because the gases enveloping a world represent an active and important part of its evolution, understanding our atmosphere could teach us a lot about not only our planet, but also other bodies in our solar system and beyond.

"Though so much about them remains unknown, planetary atmospheres are clearly vital to the study of our solar system," Ciaccio wrote. "Studying them can not only give us clues to the history of planets, but it can help us understand our own planet's atmosphere." **— MEGAN McCHAIN**

May 1999

10 years ago in *Astronomy*

In the May 1999 issue of *Astronomy*, current Editor David J. Eicher (then the managing editor) wrote about galactic mysteries in "Galactic genesis." Eicher discussed how astronomers are trying to understand galaxies through a variety of observations and models.

Many questions about galaxies remain unanswered today, such as how the first galaxies formed. However, one question Eicher discussed is well established. After years of research, most astronomers are confident larger galaxies form by smaller structures coalescing.

Understanding galaxies helps astronomers piece together how the universe has evolved. "Edwin P. Hubble realized 75 years ago that galaxies are vast islands of stars, gas and dust," Eicher wrote, "but astronomers and cosmologists are still wrestling with the most basic questions about them." And this is still accurate today. **— L. K.**

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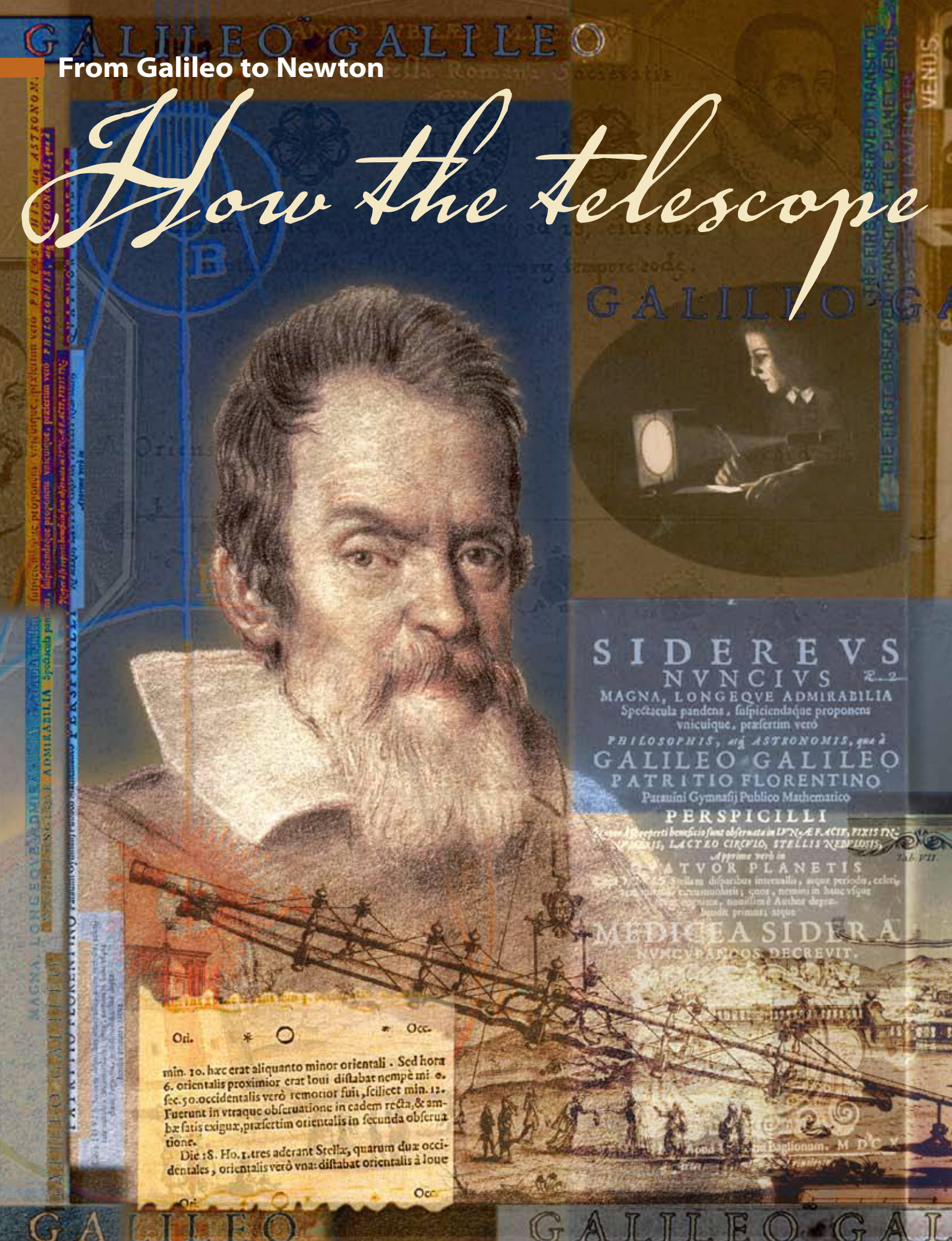
Per Person based on Double Occupancy

From Galileo to Newton

How the telescope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remade the universe

Within half a century of its invention in 1608, the telescope had transformed our view of the cosmos and Earth's place in it. **by Raymond Shubinski**

No one questions that the invention of the telescope transformed science. Yet far fewer people realize this 1608 invention also changed philosophy, culture, and religion. In the first half of the 17th century, this new optical instrument went from a toy to an agent of spectacular change.

At first, seeing and believing did not go hand in hand. Some wondered whether this newfangled combination of lenses could trick the senses into perceiving falsehoods. It took the dedication of many individuals to prove the telescope's value and move Earth to its rightful place in the cosmos.

Many scholars credit spectacle-maker Hans Lipperhey of Middelburg, Netherlands, with inventing the telescope. In late September 1608, Lipperhey presented the instrument to Prince Maurice, then head of state of the Dutch Republic. Lipperhey was looking to get a patent. Within days, two other individuals appeared in The Hague with similar instruments and similar requests.

Historians have long debated the origin of the telescope. In 1642, Pirre Borel published a book titled *The True Invention of the Telescope*. This account favors the Dutchman Zacharias Jenssen. More recently, the historical trail has led to a Spanish optician. Like the blurry images delivered by those early telescopes, the true inventor will probably remain obscure.

The device that emerged from the Netherlands was simple. It required just two lenses to produce a magnified image of a distant object. A weak convex lens, called the objective, sat at the front of the telescope tube and a strong concave lens, the eyepiece, at the rear. The story that Lipperhey accidentally discovered the telescope while inspecting two eyeglass lenses appears to be without foundation. These telescope lenses were not used for eyeglasses. In fact, if you hold a weak convex and strong concave lens close together, a distant object will appear smaller.

Hans Lipperhey independently invented the telescope in 1608, although many scholars doubt that he was the first to do so. Michael E. Bakich Library

Galileo Galilei turned his telescope to the sky for the first time in 1609. His observations launched a 50-year era of discovery that transformed our ideas about the universe.

The invention takes off

Whatever the true story of its invention, the new device spread like wildfire across Europe. At first it seemed useful only as a parlor toy or possibly as a military aid. Spanish artist Diego Velázquez captured the telescope's military importance early on. In 1625, Spanish forces conquered the Dutch city of Breda. A 1634 Velázquez painting shows Spanish General Ambrogio Spinola holding a telescope as he accepts the sword of surrender. Yet the telescope as an agent of philosophical, religious,

Astronomy: Kellie Jaeger; Galileo: © Ottavio Mario Leoni — Getty Images; Jeremiah Horrocks: Astley Hall Museum and Art Gallery; All others: Linda Hall Library of Science, Engineering, and Technology

The siege of Breda ended in 1625 when Spanish forces defeated those of the Dutch city. In this 1634 Diego Velázquez painting, notice the telescope clutched by the victorious General Ambrogio Spinola.

and scientific change was under way well before these military events.

Just 8 months after Lipperhey's presentation to Prince Maurice, an Italian professor of mathematics received news of the device and produced his own, better version. Galileo Galilei lived in Padua with his common-law wife and children. Like teachers in all eras, Galileo always looked for ways to make extra cash. At first, he sold his instrument "for far seeing" to merchants, who used the device to keep tabs on ships coming into port. Being a man of ambition and imagination, however, Galileo soon turned his telescope skyward. What he saw changed the course of the modern world.

The late 16th and early 17th centuries were turbulent times. Martin Luther had ignited the Protestant Reformation in 1517 when he nailed his 95 Theses to the doors of the Castle Church in Wittenberg, Germany. Not long thereafter, the Catholic Church initiated the Counter-Reformation, which made it risky to challenge church dogma. In 1600, an Inquisition tribunal ordered Giordano Bruno burned at the stake for holding various heretical views, including that of a Sun-centered (heliocentric) universe. Despite this dangerous climate, Galileo knew he was on to something big with his telescope and that he wasn't the only one stargazing with this new instrument.

In March 1610, Galileo rushed to publish his book *Sidereus Nuncius*, or *Sidereal Messenger*. In this small volume, Galileo challenged the accepted knowledge and wisdom of the past 2,000 years. With his improved telescope of about 30 power, he saw the Moon as a rough world full of mountains, valleys, and smooth "seas." Fuzzy objects melted into clusters of myriad stars, and the Milky Way resolved into millions of stars too faint to be seen with the unaided eye. Most amazing of all, the planet Jupiter had its own retinue of four satellites, which Galileo named the Medicean stars.

Galileo dedicated *Sidereal Messenger* to Cosimo II de' Medici in the hope of landing a job in Florence with the Grand Duke as his patron. The ploy worked, and the Grand Duke appointed Galileo his chief mathematician and philosopher. Galileo also became chief mathematician at the University of Pisa. With no teaching duties, he was free to devote himself entirely to research.

Contributing Editor **Raymond Shubinski** *is a museum and planetarium consultant who loves the history of astronomy.*

Four moons shake the world

Jupiter's four moons intrigued Galileo, and he soon compared them to a solar system in miniature. He used these observations to strengthen his argument for a Sun-centered universe, introduced during the previous century by Polish cleric Nicolas Copernicus. Galileo's lunar observations had already unseated the idea that all celestial bodies were perfect. Not only had he seen the uneven topography of the Moon's surface, but he also had measured the height of lunar mountains from the shadows they cast. Still, Galileo had to fight for change on two fronts.

In the 4th century B.C., the great Greek philosopher Aristotle refined the concept of an Earth-centered (geocentric) universe along with the basics of physics. Some 500 years later, Greek astronomer Claudius Ptolemy formalized the model. Although Aristotle was a pagan, the Catholic Church had come to view his ideas about the physical world as gospel truth. This authority was ingrained in almost all educated people.

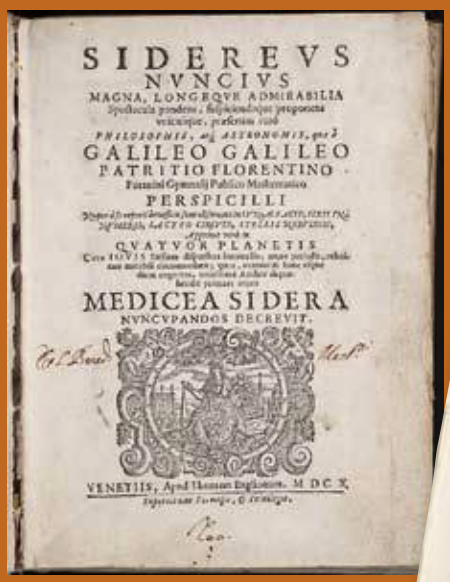
Could a simple instrument using two pieces of glass unseat 2,000 years of learning and truth? Many scholars thought the distortions inherent in these early telescopes gave views that couldn't be trusted. On a number of occasions, Galileo pointed a telescope at distant buildings during daylight to convince his audience that the nighttime views were trustworthy as well. This strategy didn't work with everyone. After all, Aristotle asserted that all things beyond Earth's realm were perfect.

> Galileo always looked for ways to make extra cash.

Galileo was not the only person studying the heavens with a telescope. German Jesuit Christoph Scheiner began to observe the Sun in 1611. Like Galileo, Scheiner discovered that this heavenly object was far from perfect.

Scheiner projected the Sun's telescopic image onto a white board and found the solar disk marked with dark spots. Was his telescope deceiving him? Scheiner was convinced of the spots' reality, and

Galileo's first views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^ ***Sidereus Nuncius*, or *Sidereal Messenger*,** laid out Galileo's initial observations. In it, he related his discoveries of myriad stars in the Milky Way, an imperfect Moon, and four satellites orbiting Jupiter.

RECENS HABITAT.

> **Galileo's First Quarter Moon** shows large craters, tall mountains, and smooth, dark "seas," all signs that imperfection exists beyond Earth's realm.

< **Jupiter's moons appear as asterisks** in Galileo's initial drawings. The Italian scientist discovered Io, Europa, and Callisto January 7, 1610, and Ganymede 6 days later.

All images: Linda Hall Library of Science, Engineering, and Technology

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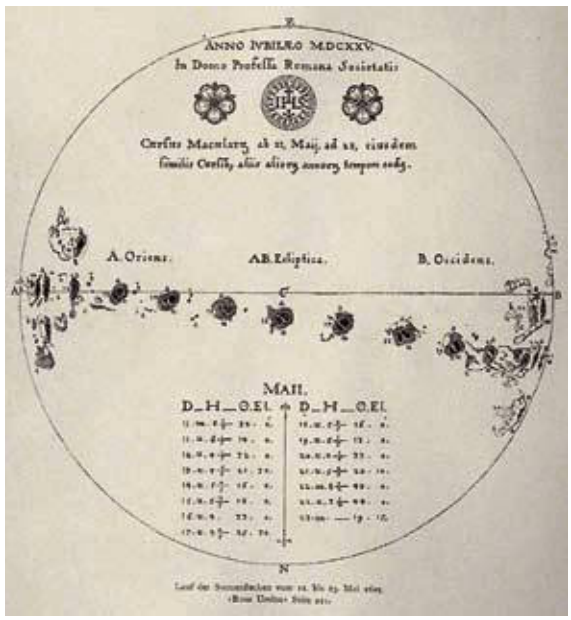
^ **Christoph Scheiner and an assistant** observed and recorded sunspots by projecting the Sun's image through a telescope onto a white card.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> **Scheiner's detailed observations** recorded dark "blemishes," another sign that all was not perfect beyond Earth. Both images: Linda Hall Library of Science, Engineering, and Technology

he published his observations in January 1612. When Galileo heard about Scheiner's discovery, he was furious and began a rancorous debate over who should get credit. Whoever saw them first, the sunspots' mere existence pounded another nail into Aristotle's coffin.

Going through a phase

The final blow came with Galileo's observations of Venus. Venus never strays far from the Sun in our sky, a fact the geocentric model explains by requiring Venus to circle a point that remains on a line between the Sun and Earth. In this configuration, Venus always would show a crescent phase.

When Galileo turned his telescope on Venus, he saw it go through all phases just like the Moon. The only explanation: Venus orbits the Sun and not Earth.

Galileo's observations, publications, and obstinacy finally brought him into full conflict with Pope Urban VIII. He ultimately denied what he knew to be truth and stopped his astronomical investigations. Galileo eventually lost his eyesight and died under house arrest.

Although Galileo made the most significant observations of Venus, he wasn't the only person with an eye on our sister planet. At the same time Galileo was scanning the heavens with his telescope, German astronomer Johannes Kepler was working through the mathematics that led to his three laws of planetary

J.W. Lavender painting, courtesy Astley Hall Museum and Art Gallery

Jeremiah Horrocks observed Venus during its 1639 transit across the Sun's face. He and fellow Englishman William Crabtree were the only persons known to see the first recorded Venus transit.

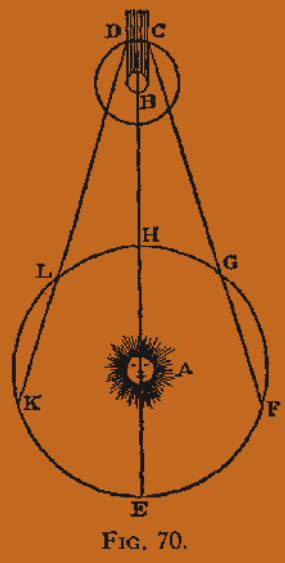


FIG. 70.

Ole Rømer measured the speed of light by observing eclipses of Jupiter's moons. When Earth and Jupiter approached each other, the times between eclipses were shorter than when the two planets were moving apart. Ole Rømer drawing

motion. Kepler based these laws on the heliocentric model of the universe, and they allowed him to make detailed predictions of the planets' motions. His calculations showed that Venus would cross in front of the Sun in 1631. Unfortunately, this transit occurred when the Sun was below the horizon throughout Europe.

A second opportunity came 8 years later. The young English cleric Jeremiah Horrocks calculated that Venus would transit the Sun late Sunday, November 24, 1639. Horrocks had to attend to his church until 3 P.M., then made a dash for his telescope. Although the day had been cloudy, the sky cleared by 3:15 P.M., and Horrocks could see Venus' small dark disk as it progressed across the Sun's face. William Crabtree, a friend of Horrocks' who lived 30 miles away, also viewed the transit. Both men used Galilean telescopes to project the Sun's image onto a white card. This simple method provided profound evidence for Kepler's laws and for the Copernican universe.

By the time Galileo died in 1642, the telescope had become an indispensable tool for nearly every astronomer. Yet the simple optics of those early refractors limited their usefulness. Poor optics even fooled Galileo. At one point, he sent out a secret communication declaring Saturn was a triple planet. In reality, he was seeing a blurred image of the planet's rings.

Expanding the telescope's power

Early telescopes had two primary limitations: They suffered from spherical and chromatic aberrations. Spherical aberration causes fuzzy or blurred images because the shape of the lens prevents light rays from coming to a common focus. Chromatic aberration produces color fringes around images.

> The challenge in building a telescope of these dimensions was as big as the scope itself.

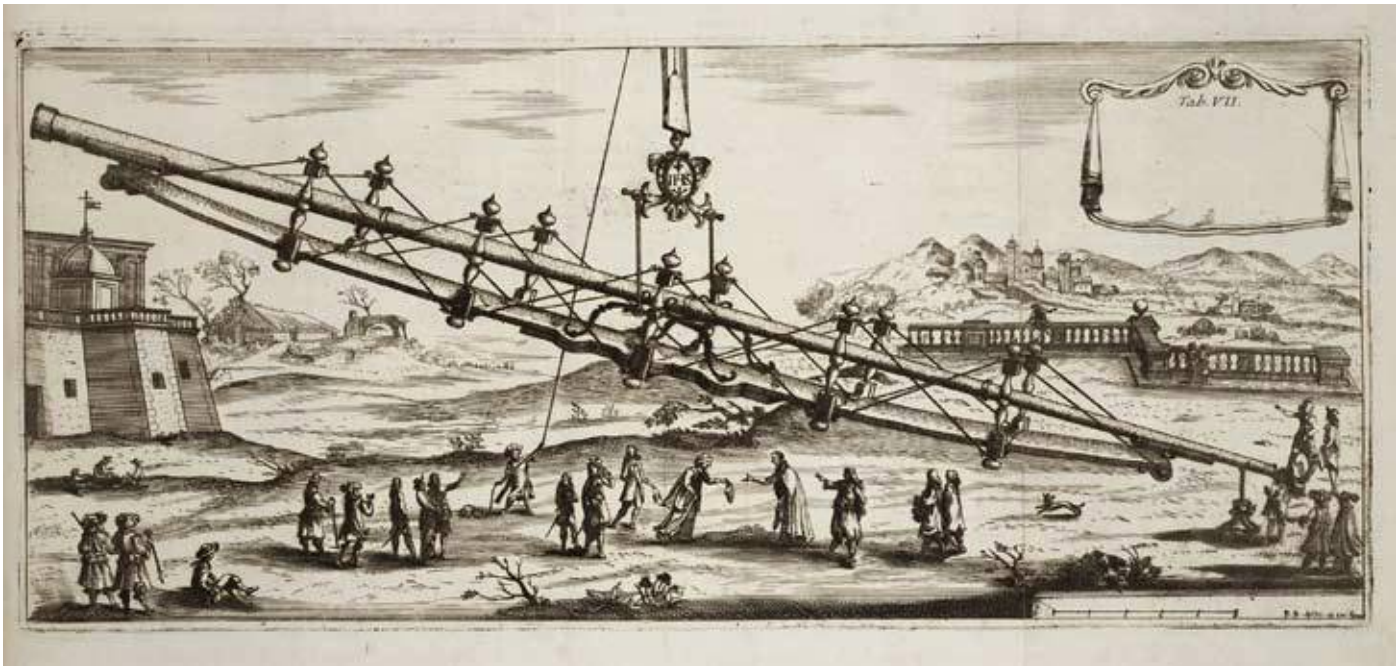
These two problems compounded the difficulty of getting clear views of planets and stars. To make matters worse, the effects intensify with greater magnifications. Telescope makers reduced spherical aberration by making the telescope's convex objective lens thinner at the edges.

The best 17th-century remedy for chromatic aberration was to shape the objective lens so it had a much longer focal length (in other words, the light focused farther from the lens). When light passes through glass, the different colors that make up white light bend by different amounts. Red bends the most and blue the least. Short-focal-length telescopes exacerbated the resulting color fringes. Seventeenth-century telescope-makers compensated by making their instruments incredibly long.

In the early 1640s, successful brewer Johannes Hevelius turned his energy to astronomy. From his rooftop observatory in Danzig (now Gdansk, Poland), Hevelius began observing the Moon with refracting telescopes about 12 feet long. He recorded hundreds of lunar features and published a famous lunar atlas, *Selenographia*, in 1647.

In the mid-1650s, Hevelius heard about the observations of Dutch brothers Constantine and Christiaan Huygens, who used exceedingly long telescopes. The brothers had established Saturn not as a triple planet, but a world surrounded by "a ring, thin, plane, nowhere attached, and inclined to the ecliptic." Word of this success set Hevelius to making telescopes up to 150 feet long with objective lenses not more than 2 inches in diameter.

The challenge in building a telescope of these dimensions was as big as the scope itself. Hevelius erected a tall mast from which he suspended sectional tubes that held the objective lens high in the air and positioned the eyepiece near the observer on the ground. A crew of sailors



Francesco Bianchini viewed Venus through this monster telescope, which was based on a design by Giuseppe Campani. Bianchini observed Venus' phases and saw vague, dark markings that he erroneously thought represented surface features. Linda Hall Library of Science, Engineering, and Technology

handled the ropes and rigging to maneuver the ungainly giant. On a visit to Danzig, Edmond Halley proclaimed the telescope "useless." Indeed, it could be used only under the best conditions.

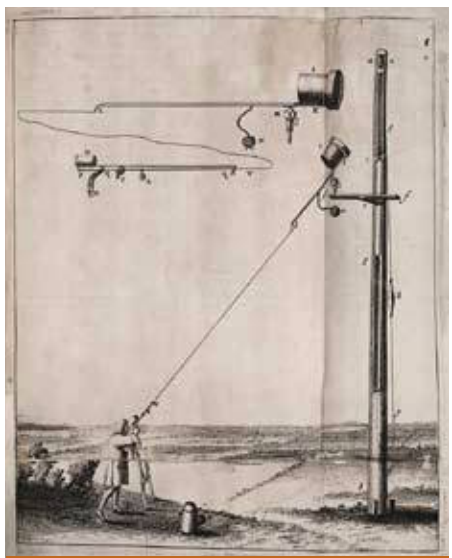
Christiaan Huygens developed a more usable "aerial telescope," also about 150 feet in length. Huygens mounted the objective lens in a short iron tube, which he attached to a ball-and-socket joint and counterbalanced with a lead weight. He then placed this entire assembly on a tall mast. Huygens operated the objective lens by a long cord attached to the eyepiece, which he mounted on a short ladder (see the drawing at right).

Huygens also improved the eyepiece by using a compound design of two thin convex lenses. Observers still use a modified version of the Huygens eyepiece. A remedy to these high-flying telescopes came from Edmond Halley's good friend, Isaac Newton. Newton invented the reflecting telescope, which uses a mirror instead of a lens to focus light, eliminating both spherical and chromatic aberration.

Tripping the light fantastic

But the refracting telescope still held surprises for astronomers, including the first measurement of the speed of light. That surprise arose from the needs of the mercantile and war ships that plied 17th-century waters. The seafarers' most pressing problem was knowing their position at sea. They could find latitude easily by observing the Sun or stars. Longitude proved tricky. To pinpoint longitude, sailors had to know the difference in time between their position and that of a fixed location, such as Greenwich Observatory near London.

Galileo had thought to use the timing of Jupiter's moons as they orbit the planet as a kind of celestial clock. Although the idea was solid, the rolling, pitching deck of a ship at sea made such detailed observations impossible.



Christiaan Huygens constructed this mammoth aerial telescope that measured nearly 150 feet from lens to eyepiece. Linda Hall Library of Science, Engineering, and Technology

In 1671, Danish astronomer Ole Rømer and his French colleague, Jean Picard, observed about 140 eclipses of Io, Jupiter's closest large moon. They viewed these eclipses from the island of Hven, Tycho's old stomping grounds near Copenhagen. Meanwhile, Italian-French astronomer Giovanni Cassini made the same observations from Paris. By comparing the time lag in the eclipse observations, the astronomers were able to determine the difference in longitude between Hven and Paris.

Rømer didn't stop there, however. He continued to time Jupiter's moons. He soon noticed a shift from the predicted eclipse times. He realized that as Earth approached Jupiter, the time between eclipses shortened. As Earth pulled away from Jupiter, the time increased.

Rømer deduced that light must have a finite speed. He calculated that light travels at roughly 125,000 miles per second. Although Rømer's value was too small, the idea was sound. Not all scientists fully accepted this astounding discovery. It would take another 50 years, until 1727, before English astronomer James Bradley confirmed light's finite speed.

Within half a century of its invention, the telescope had allowed astronomers to remake the universe. The cosmic changes launched by this instrument continue to reverberate 400 years later.

The telescope's 400-year revolution

Sir Isaac Newton made the first reflecting telescope. He chose mirrors over lenses after his research showed that light comprises a spectrum of colors. Science Museum

Early telescopes were about 1 inch wide; today's span some 33 feet. Here's how this crucial tool moved forward. **by Liz Kruesi**

When Galileo Galilei pointed his looking glass to the sky in 1609, he viewed a world before unseen. Even though his refractor had a tiny field of view and distorted optics, he was the first human to observe the Moon as an imperfect sphere. This new capability to observe proved the era's scientific beliefs were inaccurate.

Since 1609, many observers have opened a new door to the universe with their modified looking glasses. The telescope's transformation has encapsulated 400 years of trial and error and awe.

Rise of the reflector

The first telescopes — refractors — used lenses to collect and focus light. However, a lens focuses different colors of light to different points. This effect — called chromatic aberration — causes color fringes around objects viewed with early refractors. To resolve this problem, early observers looked away from refractors and toward telescopes made of mirrors.

Sir Isaac Newton determined one could not make an achromatic telescope lens. In 1668, he instead made a reflecting telescope using speculum metal — an alloy of copper and tin. He used a spherical primary mirror and a flat secondary mirror angled 45° to reflect the light to one side of the tube (and also to the attached eyepiece). This scope's aperture was 1⅓ inches and magnified objects 40 times.

Although Newton built the first reflector, he wasn't the one who came up with the concept. In 1663, James Gregory designed a two-mirror combination. His concept featured a concave parabolic primary mirror and a concave ellipsoid secondary mirror. Unfortunately, in the 1660s no one could grind a mirror surface other than spherical, and therefore the Gregorian design was useless.

The third reflecting telescope design came in 1672 from Frenchman Laurent Cassegrain. In the Cassegrain design, while the primary mirror is a parabola like the Gregorian, the secondary mirror is a convex hyperboloid instead of a concave ellipsoid. But like the Gregorian, because of technology limitations, it took years for the Cassegrain design to move past the proposal stage.

These early reflecting telescopes also suffered from a type of aberration, called spherical aberration. When a telescope uses a spherical mirror, light rays near the mirror's center reflect to a different focal point than light rays near its outer edges. Until opticians could grind mirrors into other shapes, spherical aberration would remain a problem and mirrors would take a back seat to refractors.

Return of the refractors

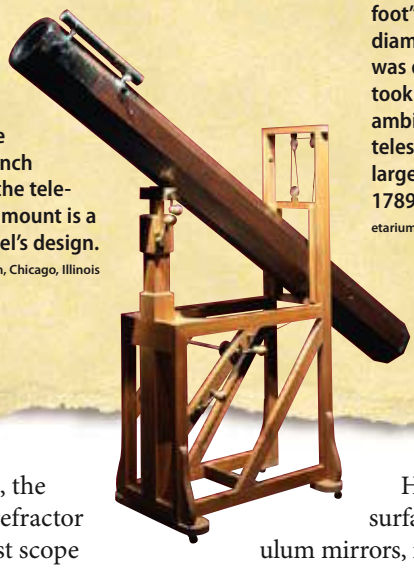
Refracting telescopes also had problems besides their chromatic aberration. Their glass had imperfections, and they had extremely long tubes to accommodate the primary lens' focal length. In 1729, the first of these problems experienced drastic improvement with Chester Moor Hall's development of the achromatic lens. Hall's design combined two pieces of glass — each with a different index of refraction, or how much the glass bends light. Using concave flint glass and convex crown glass, Hall created a lens that brought most colors to the same focus.

In 1765, Peter Dollond found a way to eliminate chromatic aberration altogether.

Liz Kruesi *is an associate editor of* Astronomy.

The 9.5-inch Dorpat refractor was the first telescope to use an equatorial mount. Joseph Fraunhofer learned in the early 1800s how to make large lenses free from imperfections. He made this excellent refractor in 1824.
Andres Kuperjanov, Tartu Old Observatory

John Hadley's Gregorian reflecting telescope was one of the first telescopes to use a parabolic mirror. This telescope, from 1724, was made just a few years after Hadley's first Gregorian. Science Museum



> William Herschel used a telescope similar to this one to discover Uranus in 1781. This Newtonian reflecting telescope is 7 feet long to house the focal length of a roughly 6-inch diameter mirror. In this image, the telescope tube is original while the mount is a modern reproduction of Herschel's design.
Courtesy Adler Planetarium & Astronomy Museum, Chicago, Illinois

The 40-foot telescope, with a primary mirror 48 inches in diameter, was William Herschel's largest scope, but it wasn't his favorite. Instead, he preferred his "large 20-foot" that had an 18.5-inch diameter mirror. The 40-foot was difficult to maneuver and took too long to adjust to the ambient temperature. This telescope remained the largest in the world from 1789 until 1845. Courtesy Adler Planetarium & Astronomy Museum, Chicago, Illinois

Dollond fit three different lenses together to create the triplet objective. Unfortunately, even with this major improvement, refractors still had a problem: Lenses larger than about 4 inches contained imperfections, such as bubbles and streaks, that altered the appearance of celestial objects. These setbacks halted the evolution of refractors until someone could make a larger lens free of defects.

Enter Pierre Louis Guinand, a Swiss craftsman. In 1785, after almost 20 years of trial and error, Guinand invented a new technique that used a porous clay stirrer instead of a wood rod to blend the molten glass. With this fireclay stirrer, bubbles rose to the surface and the glass stayed mixed longer. Guinand's lenses, as a result, were nearly free of defects.

Through collaboration with a German financing firm, Guinand taught his lens-making methods to physicist Joseph Fraunhofer. Fraunhofer built a number of excellent telescopes. In fact, the 9.5-inch diameter Dorpat refractor he built in 1824 was the first scope to use an equatorial mount.

Reflectors play catch-up

Reflecting telescopes spent 40 years at a standstill until opticians figured out how to grind non-spherical mirrors. In 1721, John Hadley taught himself how to grind speculum metal, and he and his two brothers ground a parabolic mirror for a Gregorian telescope.

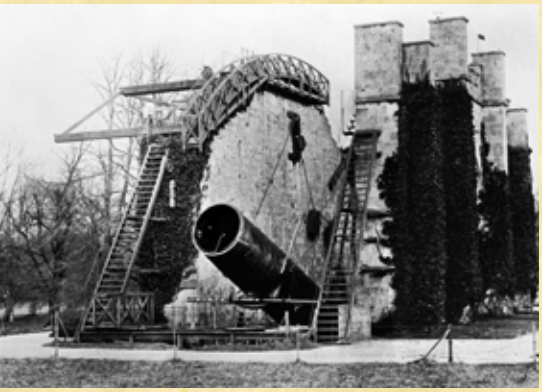
Reflecting telescopes spent 40 years at a standstill until opticians figured out how to grind non-spherical mirrors.

Few advanced telescope-making more than German-born English astronomer William Herschel. In 1773, he began producing small telescopes (a few inches in diameter). In 1778, however, he polished a speculum mirror about 6 inches in diameter. This telescope, 7 feet long and of Newtonian design, was the instrument he used to discover the planet Uranus some 2½ years later.

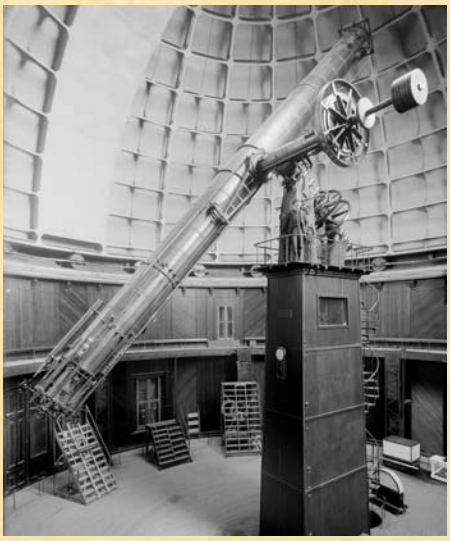
Herschel's reflecting surfaces, like other speculum mirrors, required constant polishing. For most of his telescopes, he'd create two mirrors so that he could continue observing while polishing the other. In 1783, Herschel built his most-used telescope; it had a roughly 18.5-inch diameter mirror and a 20-foot-long tube. His next scope was a 48-inch aperture instrument. Herschel housed this mirror in a 40-foot-long tube. He raised and lowered his 20-foot and 40-foot telescope tubes using cables supported by wood frames. His 40-foot monster was the largest telescope from 1789 until William Parsons, the third Earl of Rosse, completed his 72-inch version in 1845.

Parsons wanted a bigger and better telescope than Herschel, and the only way he could get such a scope was to build his own. Lucky for him, he also had unlimited resources (both money and materials). So he set to work at Birr Castle, Ireland.

Parsons first cast a 15-inch, then a 24-inch, and finally a 36-inch mirror to perfect his method. His 36-inch mirror produced brighter and sharper images



The Leviathan of Parsonstown was the largest telescope in the world from 1845 until the Hooker 100-inch surpassed it in 1917. The Leviathan fell into disrepair in 1908 and was dismantled in 1914. William Parsons used this 72-inch telescope to observe the spiral structure of numerous "nebulae," including the Whirlpool Galaxy (M51). Science Museum



Lick Observatory

The Lick 36-inch refractor saw first light in 1888. One of the two lens blanks broke during transport, and it took some 18 attempts to make a replacement blank. This Clark telescope is still used today for infrequent research and public viewing.

Special Collections Research Center, University of Chicago Library

The largest working refractor ever built, the Yerkes 40-inch, saw first light in 1897. Charles Tyson Yerkes gave the money — some $300,000 — needed to fund the 40-inch telescope, mount, and observatory.

than Herschel's mirrors. So what was Parsons' next project? Build it bigger. He did just that by doubling the diameter.

After his 72-inch mirror was cast, it took more than 16 weeks to cool. During the polishing process, the mirror broke. Undeterred, Parsons cast a second, third, fourth, and finally fifth mirror. This huge mirror weighed 4 tons — too much for wood beams to support it. So Parsons built stone walls to hold the 56-foot-long tube. Parsons and his assistants completed this "Leviathan of Parsonstown" in 1845.

Because of the mounting system, the scope could move only up and down and slightly side to side, which limited its view. The weather never seemed to cooperate. Parsons observed the spiral structure of the Whirlpool Galaxy (M51) and other "nebulae," but because of limited observing time, the scope proved less than useful in many ways. It remained, however, the world's largest telescope ever built until 1917.

The last large telescope sporting a speculum mirror was completed in 1868. Six years earlier, a committee of astronomers and telescope-makers discussed building a Southern Hemisphere telescope. The committee chose a 48-inch diameter reflecting telescope for Melbourne, Australia. And even though silvered glass had recently made an appearance, they chose a speculum mirror because they felt silver-on-glass would tarnish too quickly and possibly damage or break as a result of the weather. They used the Melbourne telescope for about 10 years before the scope fell into disrepair. And so the era of metal mirrors ended. The advancement of large reflectors again stalled for decades. Because speculum mirrors tarnished easily and coated mirrors were still in their infancy, observers typically chose glass refractors over reflectors.

Giant refractors emerge

After refractors moved past the 4-inch size barrier, it was only a matter of time before large refractors were everywhere.

After refractors moved past the 4-inch size barrier, it was only a matter of time before large refractors were everywhere.

With interest in astronomy growing, Boston citizens pooled together their resources for a 15-inch refractor for Harvard College Observatory. This telescope, completed in 1847, was the largest in the United States for 20 years, finally surpassed in size by one from a top-notch American optics firm.

Upon peering through the Harvard refractor, Alvan Clark felt he could create a superior lens. Clark was a portrait painter who occasionally dabbled in mirror- and lens-making, but he wasn't trained as an optician or astronomer. After learning the trade, he would build some of the finest refractors in the world.

The Alvan Clark & Sons partnership started producing small lenses in 1844. By the end of the century, Clark refracting telescopes were in almost every large U.S. observatory. Clark made the world's largest refractor five different times.

In 1862, Clark completed an 18½-inch equatorial for the Old University of Chicago. This telescope is still used today at the Dearborn Observatory at Northwestern University, north of Chicago.

In 1870, the U.S. Naval Observatory asked its astronomer, Simon Newcomb, to find the best and biggest telescope $50,000 could buy. He contracted Clark, who created a doublet lens — one piece flint and the other crown — that was 26 inches in diameter and weighed 110 pounds. In 1873, the Naval Observatory telescope saw first light, and it remained the largest refractor in the world for 15 years.

The 1870s through 1890s saw many large refractors. In 1885, Clark began work on the Lick Observatory 36-inch refracting telescope, which would sit atop Mount Hamilton in California. The site, roughly 4,200 feet above sea level, provided optimal observing conditions.

Mount Wilson Observatory

< George Ellery Hale had the 60-inch glass blank before he secured the funds to build such a telescope. Shortly after the Yerkes refractor was complete, he moved to California, obtained the funding from the Carnegie Institution, and began construction of the 60-inch reflector.

The Hooker 100-inch telescope joined the 60-inch atop Mount Wilson in 1917. This telescope, another of George Ellery Hale's projects, was the largest in the world until 1948. Mount Wilson Observatory

Image courtesy Dr. T. H. Jarrett (IPAC/Caltech)

The massive Hale 200-inch telescope was under construction for 21 years. George Ellery Hale, who secured the funding for the 200-inch, passed away in 1938. Almost 1,000 people attended the 1948 dedication of the Hale 200-inch reflector.

Once complete, the Lick 36-inch remained the largest refractor for only a few years — from 1888 until 1897.

A few years later, the University of Southern California commissioned a 40-inch objective lens from Clark. However, the funds fell through, and Clark had two glass disks for a 40-inch objective lens and no buyers. Enter George Ellery Hale of the University of Chicago.

Recognizing the importance of an observatory for an astrophysics academic program, Hale and the university's president convinced Charles Tyson Yerkes, a Chicago railway magnate, to pay for the telescope lens, mount, and the rest of the observatory. Hale chose a site in southeastern Wisconsin, on the shore of Lake Geneva. The bitterly cold nights allowed for clear seeing.

The Yerkes 40-inch saw first light in 1897. This giant telescope's tube is 64 feet long and weighs 6 tons; this weight doesn't include the mounting system. The lenses themselves weigh some 500 pounds. The Yerkes refractor, still in use today, remains the largest working refracting telescope in the world.

Unfortunately, bigger and thicker lenses sag under their own weight. They also absorb some of the incoming light. These problems, combined with advances in mirror-making, made reflecting telescopes popular again. The 20th century witnessed the rise of large reflectors.

Reflectors make a comeback

Astronomers' desire for additional light-gathering power for photographs and spectroscopic research helped revive the reflecting telescope. New technology — using aluminum-coated mirrors instead of metal — meant mirrors required little upkeep. They were also much lighter and more maneuverable. While opticians were building large coated glass reflectors in other countries, the United States was slow to adopt them. Hale was instrumental in the push toward large reflectors.

Even before the 40-inch Yerkes refractor was complete, Hale began planning a 60-inch reflector. He decided on a 60-inch atop Mount Wilson in California, as the upper Midwest isn't home to the best observing conditions. Hale hired George W. Ritchey, an optician who made high-quality telescope mirrors, including a 24-inch used at Yerkes Observatory. Ritchey's task was to make the 60-inch mirror. He created essentially a clean room in his polishing shop: He sealed the windows, kept the temperature as constant as possible, suspended a canvas screen over the mirror to protect it from dust, and wore a surgeon's cap and gown. In 1908, the 60-inch reflector began operation.

Hale didn't stop there. A few years later, Los Angeles businessman John D. Hooker, along with the Carnegie Institution, provided the money for a 100-inch reflector, also atop Mount Wilson. Upon completion, the entire instrument — mirror, tube, and counterweights — weighed 100 tons, yet could move with great accuracy. The 100-inch Hooker telescope saw first light in 1917, and regular research began in 1918. After more than 70 years, a telescope trumped the Leviathan of Parsonstown in size.

Progressively, reflectors got bigger as technology advanced. The Hooker telescope pushed the limit on glass mirrors, so future mirrors used different materials coated with aluminum. The 200-inch Hale reflector at Palomar Mountain held the rank of the largest telescope in the world for almost 30 years, from 1948 until 1975. The Russian BTA-6 (Big Telescope Alt-azimuthal) was the 236-inch reflector that beat out the Hale 200-inch in 1975, but the Hale's optics remained superior. In the 1990s, astronomers built a number of massive reflectors to overtake the Hale's resolving power.

By the end of the 20th century, astronomers were using segmented mirrors to create ever-larger reflecting telescopes. To overcome atmospheric distortion, they've launched telescopes into orbit around our planet. The quest to see and understand more about our universe is ongoing. It's a goal set forth 400 years ago and it doesn't show signs of stopping.

Visit www.Astronomy.com/toc for information about the first reflectors' optics.

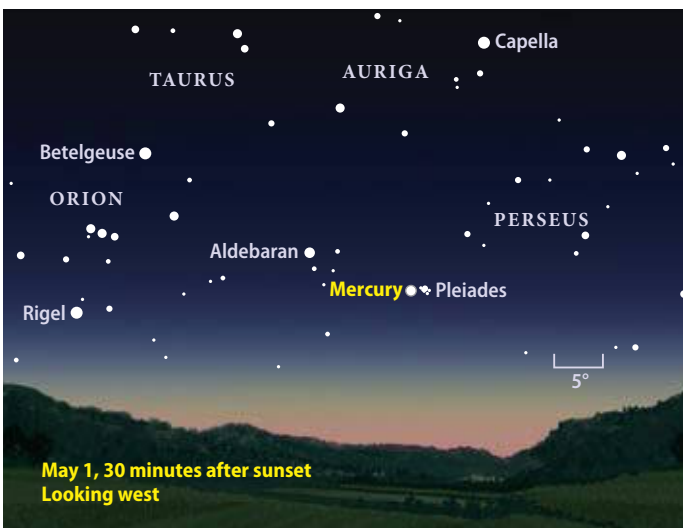
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

May 09

Jupiter's moons meet

The First Quarter Moon appears twice this month, on the evenings of May 1 and 30. The stark relief along the day-night divide convinced Galileo that not all heavenly bodies are perfect spheres. Emanuele Colognato



Mercury lies next to the Pleiades star cluster after sunset in early May. Binoculars will give you crisp views of this pair. *Astronomy*: Roen Kelly

May shapes up as a planet observer's dream. Mercury wraps up its finest evening appearance of 2009, Saturn gives us our best view of its rings until year's end, Jupiter passes a single Moon's width from distant Neptune, and brilliant Venus punctuates the morning sky.

This spring's sky also offers a great opportunity to participate in the International Year of Astronomy. One of the program's objectives is to provide people with their first views through telescopes. Warm May evenings present a perfect setting to give your children, friends, and neighbors their unforgettable first peeks. You'll have plenty of choices to wow them with this month, including all of Galileo's paradigm-changing observations.

As the sky darkens May 1, look high in the southwest to find the First Quarter Moon. Good binoculars or a small telescope will reveal rugged mountains and deep craters along the terminator — the line that divides day from night on the Moon. Galileo first saw these "imperfections" in 1609. The Italian scientist's first use of an astronomical telescope 400 years ago is the main reason why the International Astronomical Union and UNESCO planned the International Year of Astronomy for 2009.

40 First Quarter Moon times two
40 Mercury meets the Pleiades
53 Meteor watch
53 Rising Moon
54 When to view the planets
54 Jupiter's moons come together
54 Comet search
55 Locating asteroids
55 Venus bright before dawn

Visible to the naked eye
Visible with binoculars
Visible with a telescope

The evening of May 1 also provides the month's best view of **Mercury**. The innermost planet pops out of evening twilight 30 minutes after the Sun sets. As the sky darkens, the 1st-magnitude planet appears next to the Pleiades star cluster (M45), which begins to emerge from twilight soon after Mercury. Swing your scope to Mercury before the planet drops too low. You'll see its 9"-diameter disk, now about one-quarter illuminated.

Although Mercury sets more than 90 minutes after the Sun May 1, it quickly descends into evening twilight as the month progresses. By

— *Continued on page 53*

Scoping out the great discoveries

From Jupiter's moons to dark energy, scientists have used the telescope to make many extraordinary discoveries.

by Richard Talcott

∧ **1610:** Galileo's first lunar observations show tall mountains and deep craters all across our satellite's surface. They prove to him that not all objects beyond Earth's realm are the perfect spheres prevailing attitudes had held. Adam Block/NOAO/AURA/NSF

When some early 17th-century Dutch spectacle-makers first aligned two lenses and saw distant objects appear closer, little did they realize their invention would change astronomy. It didn't take long. Just a year later, in 1609, Italian scientist Galileo Galilei built an improved telescope and changed our view of the universe.

Galileo picked off the heavens' low-hanging fruit. He quickly discovered mountains on the Moon, myriad stars in the Milky Way, four moons orbiting Jupiter, and the phases of Venus — all things apparent through his small (barely 1 inch in diameter) telescope.

Most of the great discoveries that followed Galileo's relied on bigger and better telescopes. Larger apertures revealed ever-fainter objects, and improved optics brought sharper views. In 1668, Britain's famed Isaac Newton built the first reflecting telescope, which used a mirror to gather light instead of the lenses Galileo employed. Using mirrors allowed new possibilities because reflectors could be made larger and brought all colors to the same focus. By the 1920s, giant reflectors had shown that the Milky Way is not the universe's only galaxy and that the cosmos is expanding rapidly.

Another leap forward came when astronomers built telescopes to observe the universe at other wavelengths. Radio waves revealed exotic new objects, like quasars and pulsars, while X rays and other high-energy forms of radiation showed the universe to be a violent place. Some telescopes went beyond the electromagnetic spectrum, searching for gravity waves and neutrinos.

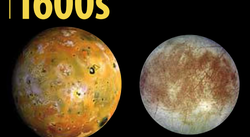
Many modern instruments don't even stand on terra firma. Astronomers launched telescopes into Earth orbit and beyond. Above the distorting effects of Earth's atmosphere, the Hubble Space Telescope gets unprecedented views of the universe in visible light. And a host of other telescopes observe radiation at both longer and shorter wavelengths, which the atmosphere blocks to varying degrees.

The telescope has served astronomers well during the last 400 years. There's no telling where this versatile instrument will lead us in the decades ahead. ➔

Richard Talcott *is a senior editor of* Astronomy.

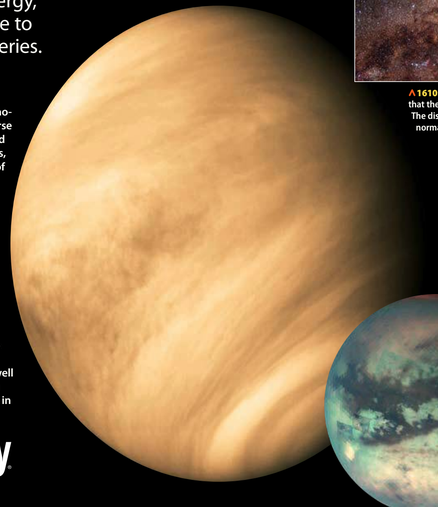
Astronomy magazine

1600s



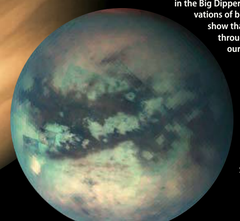
∧ **1610:** Galileo discovers four moons circling Jupiter. It is the first time anyone has seen a center of motion other than Earth, which puts another nail into the coffin of the geocentric model of the universe. Spacecraft later show these moons — Io, Europa, Ganymede, and Callisto (left to right) — to be worlds in their own right. NASA/JPL

∨ **1610:** Galileo witnesses Venus going through phases just like the Moon does. According to the geocentric model, Venus should always show a crescent. The gibbous phases he sees as Venus moves to the farside of the Sun convinces him the Sun lies at the solar system's center. NASA

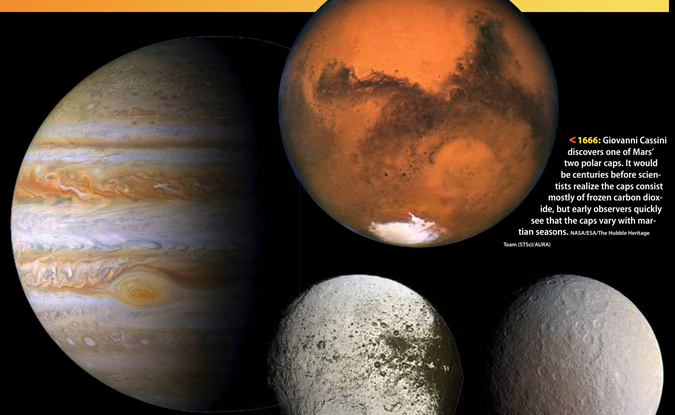


∧ **1610:** When Galileo views the Milky Way with his telescope, he finds that the narrow band of light resolves into more stars than he can count. The discovery proves to him that a telescope can reveal things beyond normal human perception. Mike Salway

∧ **1650:** Giovanni Riccioli discovers that the bright star Mizar in the Big Dipper's handle is a binary system. Observations of binary systems would eventually show that Newton's laws of physics hold throughout the universe and not just in our corner of it. Frederick Ringwald



< **1655:** Christiaan Huygens discovers Titan, Saturn's largest moon and the second-biggest moon in the solar system (after Jupiter's Ganymede). Huygens' discovery would open the floodgates to finding more moons in the late 17th century, particularly around Saturn. NASA/JPL/University of Arizona



∧ **1665:** Giovanni Cassini discerns a large reddish oval on Jupiter: the Great Red Spot. Centuries later, astronomers realize the spot is a giant storm system larger than Earth swirling in the massive planet's cloud tops. NASA/JPL/SSI

∧ **1675:** While observing Jupiter's moons as the planet eclipses them, Ole Romer realizes that the eclipse timings don't stay constant but speed up and lag as Earth's distance to Jupiter changes. He correctly deduces that light's finite speed causes the effect and makes the first crude approximation of this speed. (In this photo, Io and its shadow appear in front of Jupiter's clouds.) NASA/JPL/SSI

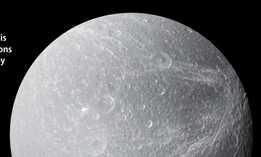
∧ **1671:** Giovanni Cassini discovers Iapetus, Saturn's outermost large moon. Interestingly, he notes that he can see it only when it lies west of the planet but not when it lies to the east. He correctly concludes that Iapetus has one dark and one bright hemisphere, and his telescope can reveal the moon only when the bright side faces Earth. NASA/JPL/SSI

> **1684:** Giovanni Cassini continues his assault on Saturn, turning up the moons Tethys and Dione. This photo, taken by the spacecraft that carries Cassini's name, shows the cratered landscape and icy streaks of Dione's surface. NASA/JPL/SSI

< **1666:** Giovanni Cassini discovers one of Mars' two polar caps. It would be centuries before scientists realize the caps consist mostly of frozen carbon dioxide, but early observers quickly see that the caps vary with martian seasons. NASA/ESA/The Hubble Heritage Team (STScI/AURA)

∧ **1672:** During the course of Cassini's continuing observations of Saturn, he discovers the planet's third moon, Rhea. Although it is Saturn's second-brightest moon, after Titan, he finds it after Iapetus because Rhea orbits much closer to the planet's glare. NASA/JPL/SSI

< **1676:** Giovanni Cassini discovers a dark gap in the rings of Saturn. Now known as the "Cassini division," this is the first observational proof that the rings aren't solid. Spacecraft have since shown that the broad rings visible from Earth consist of thousands of narrow ringlets governed by the gravitational pulls of the planet's moons. NASA/ESA/The Hubble Heritage Team (STScI/AURA)



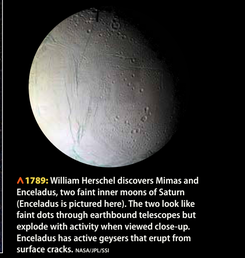
1700s

> **1761:** While observing the first transit of Venus across the Sun's face in 122 years, Mikhail Lomonosov discovers that Venus has an atmosphere. Although it initially fuels speculation that the planet could be earthlike, we now know Venus' atmosphere is too dense and toxic to support life. Francis Reddy

∨ **1764:** Famed comet hunter Charles Messier discovers the Dumbbell Nebula in the constellation Vulpecula. This is the first planetary nebula ever sighted, and the first type of deep-sky object that no one had ever seen before. G. Jacoby/WIYN/NOAO/NSF

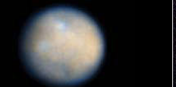
> **1784:** John Goodricke discovers that the star Delta Cephei varies in brightness. Although this isn't the first variable star known (observers spotted Mira's variability before the telescope's invention), Delta Cephei turns out to be the first of many so-called Cepheid variables. Astronomers use these stars to gauge distances in our galaxy and beyond. Bill and Sally Fletcher

∧ **1781:** William Herschel spies Uranus, the first planet discovered since antiquity. Although Uranus glows bright enough to see with the naked eyes, no one had recognized its movement against the background stars — a telltale sign it belongs to the solar system — until Herschel tracked it through his scope. NASA/Erich Karkoschka (University of Arizona)



∧ **1789:** William Herschel discovers Mimas and Enceladus, two faint inner moons of Saturn (Enceladus is pictured here). The two look like faint dots through earthbound telescopes but explode with activity when viewed close-up. Enceladus has active geysers that erupt from surface cracks. NASA/JPL/SSI

1800s

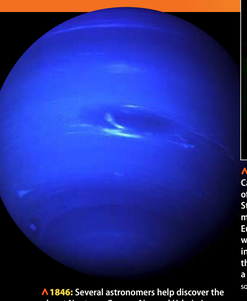


∧ **1801:** On the first night of the new century, Giuseppe Piazzi discovers Ceres — a rocky object that circles the Sun between the orbits of Mars and Jupiter. At the time, many astronomers think Ceres is a planet filling the wide gap between its neighbors, but several similar objects soon turn up in the region. NASA/ESA/J. Parker (SwRI) et al.

∧ **1838:** Friedrich Bessell measures the apparent shift of the star 61 Cygni relative to more distant stars as Earth traces out its orbit around the Sun. The star's parallax yields the first accurate distance determination to an object beyond the solar system. In 61 Cygni's case, it lies a bit more than 10 light-years from Earth. Bill and Sally Fletcher

∧ **1845:** William Parsons detects spiral structure in the "nebula" cataloged as M51, the first time anyone has observed such structure. Only later do astronomers realize that deep-sky objects showing spiral shapes are actually "island universes" — galaxies — far beyond the Milky Way. NASA/ESA/S. Beckwith (STScI)/The Hubble Heritage Team (STScI/AURA)

Scoping out the great discoveries



1846: Several astronomers help discover the planet Neptune. George Airy and Urbain Leverrier calculate the object's position based on its gravitational perturbations of Uranus. Then, observers Johann Galle and Heinrich d'Arrest spot 8th-magnitude Neptune at the predicted position. NASA/JPL

1846: Shortly after Neptune's discovery, William Lassell discovers its biggest moon, Triton. Like Saturn's Enceladus, Triton features geysers, which show up as dark streaks in this Voyager 2 image. NASA/JPL/USGS

1867: Charles Wolf and Georges Rayet discover a class of star marked by intense outflows from their surfaces. Clouds of glowing gas often surround these so-called Wolf-Rayet stars. In this photo, the star WR 7 feeds the nebula dubbed Thor's Helmet. CFHT/Jean-Charles Cuillandre/Coelum

1859: While observing the Sun, Richard Carrington observes an intense brightening of its surface — the first solar flare ever seen. Strangely enough, at least to the mindset of mid-19th-century scientists, the next night Europe is bathed in vivid auroral displays. It would be decades before scientists realize the intimate connection between solar activity and the aurora. In this view from the SOHO satellite, a solar flare blazes at the Sun's lower right limb. SOHO (ESA and NASA)

1862: Alvan Clark discovers Sirius B, a dim companion to the sky's brightest star. Sirius B is the first known white dwarf, a star with the Sun's approximate mass compressed into an Earth-sized sphere. It wouldn't be until the 20th century that astronomers understood these objects. In this view, Sirius B is the dim point to Sirius' lower left. NASA/H. Bond (STScI/AURA), Barstow and M. Burleigh (University of Leicester)/J. Holberg (University of Arizona)

1868: During a total solar eclipse, Norman Lockyer turns a spectroscope on the Sun and discovers a previously unknown element in the thin layer known as the chromosphere. Scientists dub the new element "helium," after the Greek word for the Sun. Helium turns out to be the second-most abundant element in the Sun and the cosmos, after hydrogen. Tunç Tezel

1860: While watching a total solar eclipse, several people witness a huge plume of material erupting from the eclipsed Sun. This is the first observed coronal mass ejection and, like solar flares, is another sign of our star's intense activity. SOHO (ESA and NASA)

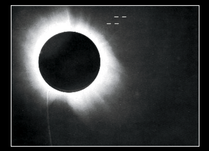
1863: William Huggins attaches the newly invented spectroscope to his telescope and turns it on the stars Aldebaran and Betelgeuse (the latter is pictured here). He finds that these stars' atmospheres contain iron, sodium, calcium, magnesium, and more — the first proof that the stars are made of materials similar to the Sun's. NASA/ESA/A. Dupree (CfA)/R. Gilliland (STScI)

1864: William Huggins continues to explore the cosmos with a spectroscope and learns that many of the sky's nebulae (like the Cone Nebula seen here) are made of luminous gas. NASA/ESA/H. Ford (JHU)/G. Illingworth (UCSC/LO)/M. Clampin (STScI)/The ACS Science Team

1877: Asaph Hall discovers Phobos and Deimos, the two moons of Mars, during an especially good apparition of the Red Planet. The two (Phobos is shown here) look similar to asteroids and may well be captured bodies from the neighboring asteroid belt. NASA/JPL/University of Arizona

1900s

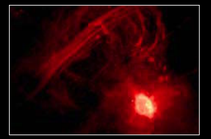
1912: Henrietta Leavitt wraps up her observations of Cepheid variable stars in the Small Magellanic Cloud (an object we now know to be a companion galaxy to the Milky Way). She learns that these stars follow a strict pattern of behavior in which the longer a star's period, the more luminous it is. This period-luminosity relation would soon allow astronomers to judge distances throughout the nearby universe. F. Winkler (Middlebury College)/The MCELS Team/NOAO/AURA/NSF



1919: Arthur Eddington provides convincing observational proof for Albert Einstein's general theory of relativity. Eddington leads a pair of expeditions to observe a total solar eclipse and compares the positions of background stars (between the lines in this photo) to where they appeared when the Sun was far away. The Sun's gravity bent the stars' light by just the amount Einstein predicted. Arthur Eddington

1923: Edwin Hubble discovers Cepheid variable stars in M31 and, using the period-luminosity relation discovered the previous decade by Henrietta Leavitt, shows that M31 lies well outside the confines of the Milky Way. Scientists name it the Andromeda Galaxy, and it becomes the first galaxy known besides the Milky Way. T. A. Rector and B. A. Wolpa/NOAO/AURA/NSF

1930: Following an exhaustive search, Clyde Tombaugh discovers Pluto. Although the search is based on the belief that a large, distant planet is perturbing Neptune's motion, Pluto turns out to be too small to affect Neptune. And in 2006, astronomers decide to demote Pluto from its status as a planet and make it a "dwarf planet." R. Albrecht (ESA/ESO-STECF)/NASA

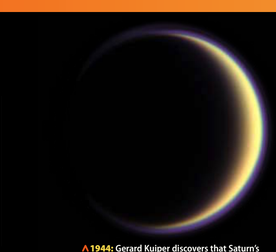


1931: Karl Jansky discovers radio emission coming from the Milky Way's center. Jansky, who had built the rotating radio antenna to study terrestrial sources of interference, thus launches radio astronomy. A more recent radio image shows an arc of emission near the Milky Way's core. NASA/AUI/NSF/F. Zadeh et al.

1915: Robert Innes discovers the star Proxima Centauri, an outlying member of the Alpha Centauri triple system and the star closest to the Sun. This red dwarf glows at 11th magnitude and is too dim to see without a telescope. It appears blue in this false-color image taken at infrared wavelengths. 2MASS/UMASS/IPAC-Caltech/NASA/NSF

1929: Edwin Hubble closes out the Roaring '20s by discovering the expansion of the universe. Hubble observes a few dozen galaxies (including M66, seen here), using Cepheid variables to get their distances and spectra to learn their speeds of recession. He finds that the farther away a galaxy lies, the faster it recedes from Earth. NOAO/AURA/NSF

1933: Fritz Zwicky discovers that the amount of visible matter contained in the galaxies of the vast Coma cluster is not enough to keep the galaxies bound together. The cluster would need about 10 times more matter than the galaxies appear to provide. This is the first indication that the universe has vast quantities of dark matter, which gives off no light but possesses gravity. NASA/ESA/The Hubble Heritage Team (STScI/AURA)

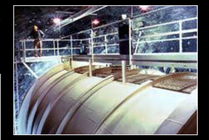


1944: Gerard Kuiper discovers that Saturn's moon Titan possesses a substantial atmosphere. Some 50 percent denser than Earth's, it is the only atmosphere surrounding a solar system moon. Titan's hazy air blocks the surface from view at visible wavelengths. The moon's surface temperature is just right to allow methane to rain out of the atmosphere and collect in lakes. NASA/JPL/SSI

1967: Jocelyn Bell discovers several peculiar objects that emit powerful radio bursts several times every second. Within a year, Thomas Gold deduces that these so-called pulsars are actually stars crushed to the density of an atomic nucleus. They arise when massive stars collapse and explode as supernovae. Many young neutron stars lie at the center of supernova remnants, like the Crab Nebula seen here. NASA/ESA/J. Hester and A. Loll (Arizona State University)

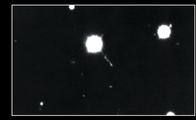
1984: Scientists prove plate tectonics operates on Earth by precisely measuring the slowly changing distances between radio telescopes observing the same distant quasar. The rate at which North America and Europe are moving apart turns out to be about 1.4 inches (3.6 centimeters) per year. NASA Earth Observatory

1948: Astronomers discover the first radio galaxies. Such an object typically has large lobes of radio emission well outside the visible portion of the galaxy. In this view of the radio galaxy NGC 1316, the two lobes appear orange with the visible part sandwiched between. NRAO/AUI/J. M. Uson



1967: Raymond Davis starts collecting data with his neutrino telescope, a tank of cleaning fluid located underground in South Dakota's Homestake mine. The device captures neutrinos emitted by nuclear reactions in the Sun's core, showing that our ideas about how stars produce energy are correct. However, Davis finds fewer neutrinos than expected because the elusive particles have a tiny mass and can change from one variety into another. Brookhaven National Lab

1986: A team of astronomers discovers that a large mass of galaxies, located some 250 million light-years away in the southern constellation Norma, is pulling the entire Virgo supercluster of galaxies toward it. The large mass, dubbed the Great Attractor, includes the Norma galaxy cluster (Abell 3627) seen here. The Attractor's immense gravity pulls us at some 13 million mph (22 million km/h). ESO

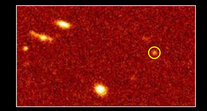


1963: Maarten Schmidt discovers that he can explain the bizarre spectra of a handful of radio-emitting objects that look visually like stars (and dubbed quasars, for quasi-stellar radio sources) if the objects lie at vast distances and their emission lines are shifted far to the red. To look as bright as they do from such large distances, quasars must be among the universe's most luminous objects. Astronomers now know that quasars are galaxies whose vast energies come from matter swirling into supermassive black holes. This image shows 3C 273, the sky's brightest quasar. NOAO/AURA/NSF

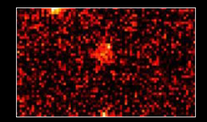
1979: Astronomers detect gravitational lensing outside the solar system. In these cases, massive galaxies or galaxy clusters distort the light from more distant objects into arcs and other odd shapes (as in the cluster Abell 1689 seen here). Einstein predicted gravitational lensing, which Arthur Eddington saw during the 1919 total solar eclipse. NASA/ESA/The ACS Science Team

1987: Scientists at three neutrino telescopes detect about two dozen of the elusive particles released when a star in the Large Magellanic Cloud explodes as Supernova 1987A. The observations prove that some supernovae result when a massive star's core collapses and that neutrinos carry away 100 times more energy than the light generated. In this photo, Supernova 1987A is the brightest point of light at lower right. Marcelo Bass/CTIO/NOAO/AURA/NSF

1991: Aleksander Wolszczan and Dale Frail discover the first planets beyond our solar system. Going against all expectations, the three planets the radio astronomers find orbit a pulsar cataloged as PSR B1257+12. The supernova that created the pulsar would have destroyed or banished any planets, so this trio must have formed later. Lynette Cook

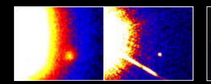


1992: David Jewitt and Jane Luu discover the first Kuiper Belt object: 1992 QB$_1$. Astronomers had long expected to find a slew of small objects lying beyond Neptune. And the predictions were right — 1992 QB$_1$ now stands among more than a thousand. As more are found, astronomers would conclude that Pluto fits the characteristics of a Kuiper Belt object, so most researchers now lump it in with the others. David Jewitt (University of Hawaii)

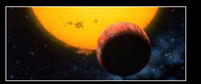


1997: A host of space-based telescopes finally confirm that gamma-ray bursts lie in the distant universe and represent the biggest cosmic explosions. The burst that proves the case arrives at Earth February 28 (hence the designation GRB 970228). Gamma-ray detectors first spot the burst, then an X-ray telescope on the BeppoSAX satellite pinpoints it, and optical scopes pick up the glow of the burst's faint and distant host galaxy. This Hubble image shows this galaxy and the burst's fading glow. Andrew Fruchter (STScI)/Elena Pian (ITSRE-CNR)/NASA

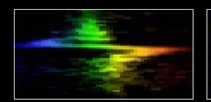
1993: Eugene and Carolyn Shoemaker join with David Levy to discover Comet Shoemaker-Levy 9. The comet isn't bright and never comes close to Earth, but it garners headlines as the first known comet to smash into a planet. Jupiter's gravity tore it into a couple of dozen pieces during a close approach in 1992, before the observing team had found it. In 1994, it comes crashing down, scarring the giant planet's cloud tops with dark clouds for months. NASA/H. Weaver and T. Smith (STScI)



1994: Astronomers for the first time discover a brown dwarf — an object that forms like a star but possesses too little mass to ignite nuclear reactions in its core. The brown dwarf orbits close to the star Gliese 229. It appears as a faint blip just off the star's limb through Palomar Observatory's 200-inch Hale Telescope (left), and as a more pronounced dot using the Hubble Space Telescope a year later (right). NASA/T. Nakajima and S. Kulkarni (Caltech)/S. Durrance and D. Golimowski (JHU)



1995: Michel Mayor and Didier Queloz discover the first planet around a Sun-like star, 51 Pegasi. Like the 1991 discovery of the pulsar planets, this one also defies expectations — it possesses as much mass as Jupiter but orbits its star in just 4.2 days at a distance only 1 percent that of Jupiter from the Sun. Many of the more than 300 now-known exoplanets also fall into the category of "hot Jupiters." Lynette Cook



1997: Astronomers finally confirm the existence of black holes with the discovery of a supermassive object at the center of the galaxy M84. The Hubble Space Telescope uses an imaging spectrograph to watch gas swirl madly around the black hole. The sharp break at the center of this image shows the gas moves around at nearly 1 million mph (1.6 million km/h) and confirms the black hole weighs at least 300 million solar masses. Gary Bower/Richard Green (NOAO)/The STIS Instrument Definition Team/ NASA

1998: Two teams of astronomers announce that the universe is expanding at an increasing rate, suggesting that a repulsive force known as dark energy has kicked cosmic expansion into overdrive. The teams discover dark energy by observing distant supernovae and finding that the farthest ones are fainter than their distances imply. In this photo, Supernova 2002dd appears as a red dot in the outskirts of its host galaxy, which lies 8 billion light-years from Earth. NASA/J. Blakeslee (JHU)

2000

2000: Astronomers confirm the existence of a supermassive black hole at the center of the Milky Way. The object, which weighs around 4 million solar masses, appears quiet most of the time, but it does flare occasionally. In this view from the Chandra X-ray Observatory, the black hole is just one of some 2,000 X-ray sources lurking in the Milky Way's core. NASA/CXC/MIT/F.K. Baganoff et al.

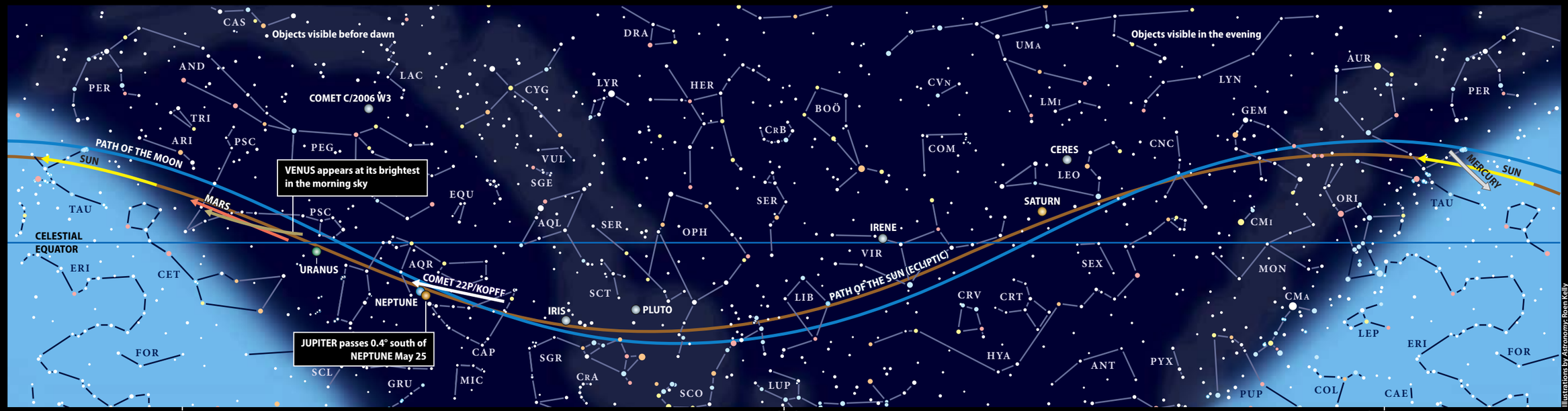
Astronomy magazine

Planets in May 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets



MOON PHASES

25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

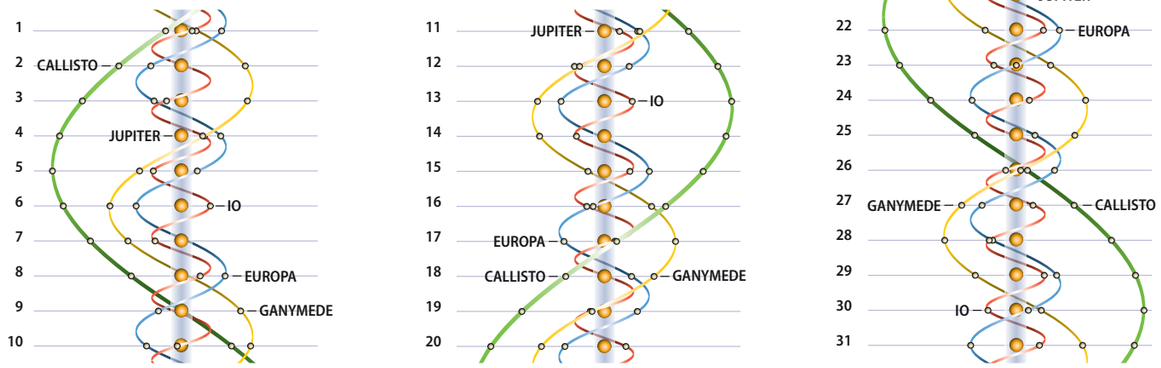
31 30 29 28 27 26 25 24 23

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	May 1	May 15	May 15	May 15	May 15	May 15	May 15	May 15	May 15
Magnitude	0.9	– 4.7	1.2	8.2	–2.3	0.8	5.9	7.9	13.9
Angular size	8.9"	31.6"	4.6"	0.6"	39.5"	18.5"	3.4"	2.3"	0.1"
Illumination	25%	36%	95%	96%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.754	0.528	2.051	2.198	4.988	9.003	20.607	30.051	30.852
Distance (AU) from Sun	0.389	0.727	1.385	2.563	5.069	9.406	20.099	30.031	31.644
Right ascension (2000.0)	3h48.4m	0h39.8m	1h04.7m	10h41.2m	21h51.5m	11h07.3m	23h45.1m	21h54.6m	18h11.5m
Declination (2000.0)	22°44'	3°37'	5°44'	21°35'	–13°45'	8°00'	–2°26'	–13°07'	–17°37'

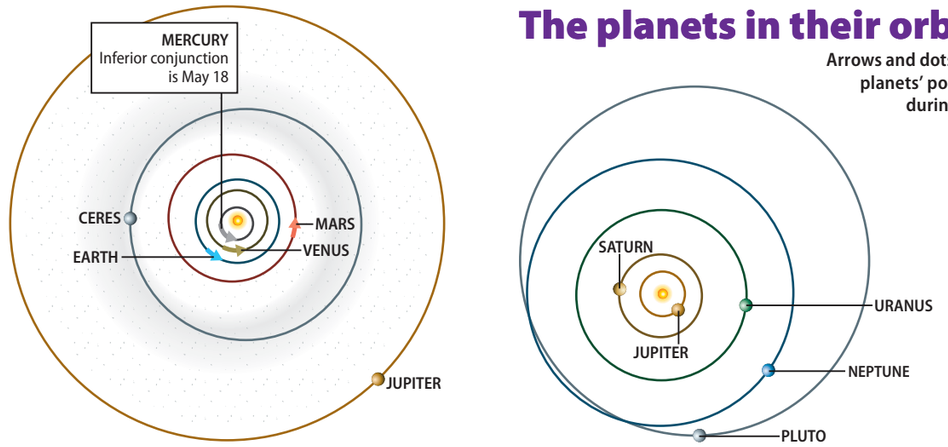
Jupiter's moons

Dots display positions of Galilean satellites at 5 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during May.



StarDome

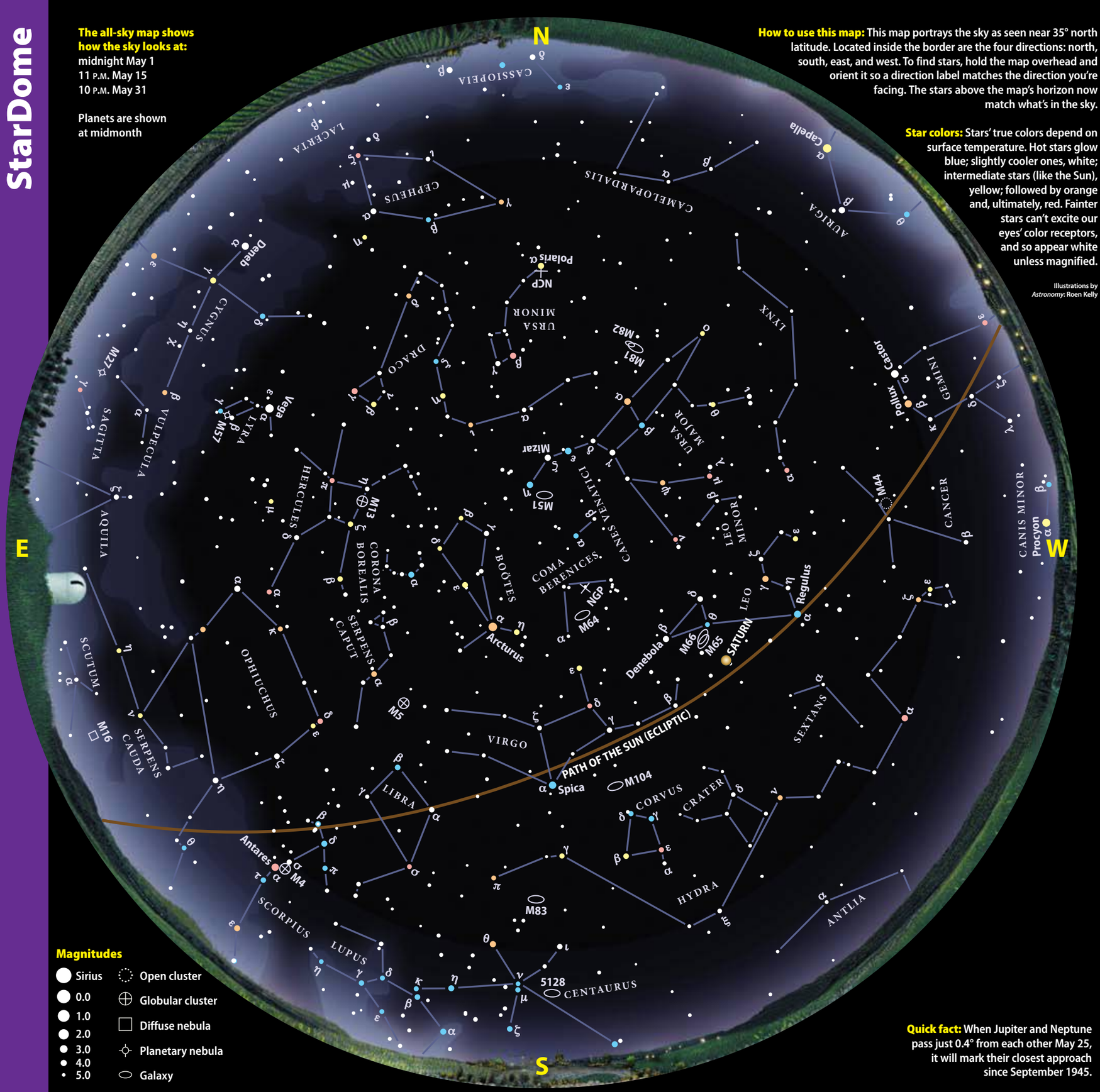
The all-sky map shows how the sky looks at:
midnight May 1
11 P.M. May 15
10 P.M. May 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: When Jupiter and Neptune pass just 0.4° from each other May 25, it will mark their closest approach since September 1945.

May 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Calendar of events

1 First Quarter Moon occurs at 4:44 P.M. EDT

Special observing date

2 Venus shines at its brightest for this morning apparition (magnitude –4.7), 11 A.M. EDT

4 The Moon passes 6° south of Saturn, 7 A.M. EDT

5 Eta Aquarid meteor shower peaks

7 Mercury is stationary, noon EDT

9 Full Moon occurs at 12:01 A.M. EDT

10 The Moon passes 0.6° north of Antares, 5 P.M. EDT

13 The Moon is at apogee (251,603 miles from Earth), 10:58 P.M. EDT

17 Last Quarter Moon occurs at 3:26 A.M. EDT

The Moon passes 3° north of Jupiter, 4 A.M. EDT

The Moon passes 3° north of Neptune, 5 A.M. EDT

17 Saturn is stationary, 3 P.M. EDT

18 Mercury is in inferior conjunction, 6 A.M. EDT

19 The M passes 5° north of Uranus, 4 P.M. EDT

21 The Moon passes 7° north of Venus, 4 A.M. EDT

The Moon passes 7° north of Mars, 4 P.M. EDT

24 New Moon occurs at 8:11 A.M. EDT

25 Jupiter passes 0.4° south of Neptune, 9 A.M. EDT

The Moon is at perigee (224,410 miles from Earth), 11:45 P.M. EDT

29 Neptune is stationary, 7 A.M. EDT

30 Mercury is stationary, noon EDT

First Quarter Moon occurs at 11:22 P.M. EDT

31 The Moon passes 6° south of Saturn, 1 P.M. EDT

For definitions of terms, log onto www.Astronomy.com/glossary.

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— *Continued from page 40*

the 5th, Mercury glows more dimly at 2nd magnitude and becomes difficult to see. The planet's best evening appearance of 2009 soon comes to an end. Mercury will reappear in the morning sky in June, but at a significantly lower altitude than in early May.

As twilight fades on May evenings, swing your gaze high in the south to spot **Saturn**. Shining at magnitude 0.8, the planet appears slightly brighter than Regulus, the luminary of Saturn's host constellation, Leo. Saturn's western motion relative to the background stars comes to a halt in mid-May when it resumes its normal eastward motion. A waxing gibbous Moon passes 6° to Saturn's lower right May 3.

Look through any telescope, and you'll immediately see Saturn's rings. Galileo saw the rings as well, but, with the poor optics of the day, he didn't recognize them as such. He referred to them as "handles." It took several decades before Dutch astronomer Christiaan Huygens deduced their true nature.

During May, the rings incline 4° to our line of sight. This isn't a lot, but it's their biggest tilt since September. The rings will start narrowing in June and become edge-on to Earth late this summer. Saturn then lies on the farside of the Sun from Earth and won't be visible.

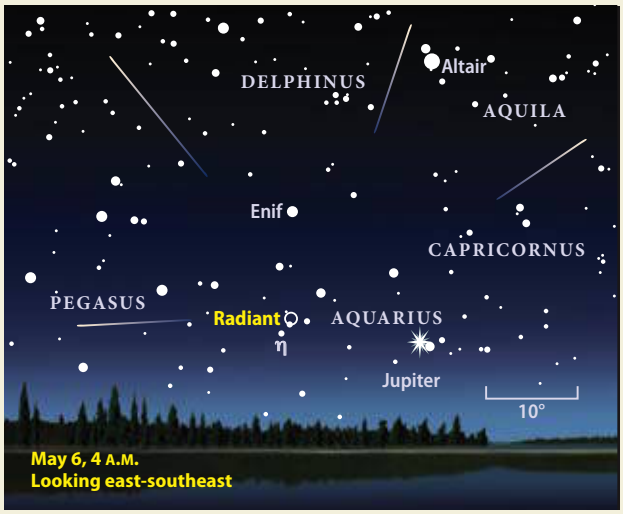
The long axis of the rings spans 42" in mid-May. This more than doubles the planet's equatorial diameter (19"). Look for Saturn's shadow falling on the rings behind the planet, immediately adjacent to the limb. A more challenging observation is to find the Cassini Division. This dark gap lies near the rings' eastern and western extremities, called the ansae.

Within several months of a ring-plane crossing, Saturn's moons and their shadows transit Saturn's face. Most telescopes will show events involving the biggest moon, Titan. These events occur every 16 days. And 8 days on either side of these transits, Saturn's shadow eclipses Titan.

North American observers have a chance to witness four

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire.* **Alister Ling** *is a meteorologist for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Eta Aquarid meteor shower peaks before dawn May 6. To see the most meteors, wait until the gibbous Moon sets around 4 A.M. local daylight time. *Astronomy:* Roen Kelly

Comet Halley's castoffs return

The consistently good Eta Aquarid meteor shower makes its annual appearance in early May. Although active from April 19 to May 28, meteor numbers remain low until the prime period between May 3 and 10. During this week, observers under ideal conditions could see about 30 meteors per hour. This number jumps to 60 per hour at the shower's peak the night of May 5/6.

The best conditions occur under dark skies in the tropics and the Southern Hemisphere where the radiant lies highest. From mid-northern latitudes, the radiant rises during early morning hours and never climbs high. Good views will come once the waxing gibbous Moon sets around 4 A.M. local daylight time May 6. Expect to see long meteor trails, some of them accompanied by persistent trains.

Eta Aquarid meteors start as small dust particles cast off by Comet 1P/Halley during its innumerable trips around the Sun. Every May, Earth encounters this debris stream. The particles burn up when they smash into our atmosphere at nearly 150,000 mph.

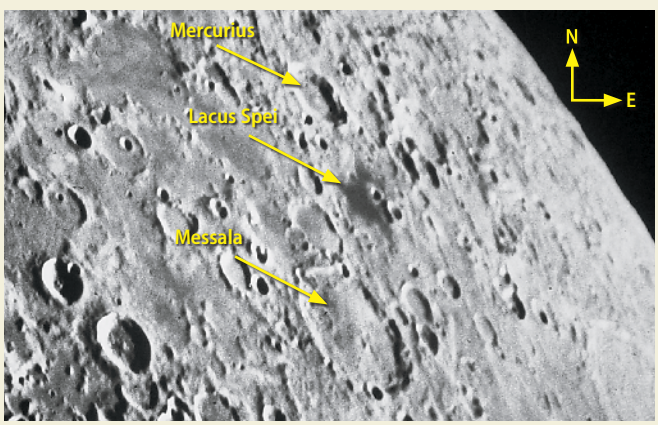
Rising Moon

Sailing on a lake of hope

Most lunar observers focus their attention on the mountains and craters that lie along the terminator — the day-night dividing line where grazing sunlight throws features into sharp relief. But in early May and again near month's end, take a few minutes to observe the Moon's northeastern limb. There you will find Lacus Spei, the Lake of Hope.

Start your search with the prominent Mare Crisium, and then head a full mare diameter north to the time-worn crater Messala. Billions of years of bombardment have rounded and softened this crater's once-sharp rim. A little farther north lies Mercurius, a much younger and therefore sharper impact crater.

The flat gray splotch that resides between these two craters goes by the Latin name Lacus Spei. This lava-filled lake grows darker as the Sun climbs higher in the lunar sky. That's because shadows disappear and the surrounding terrain brightens quickly, increasing its contrast with the lake.



The Lake of Hope, also known as Lacus Spei, is a dark, lava-filled patch between the impact craters Messala and Mercurius. *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (northwest)	Saturn (west)	Venus (east)
Saturn (south)		Mars (east)
		Jupiter (southeast)
		Uranus (east)

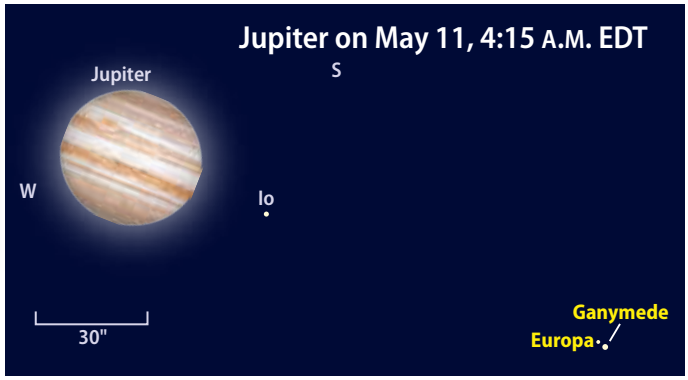
events this month. On the nights of May 6/7 and May 22/23, Saturn eclipses Titan. The first event occurs the morning of May 7 starting at 3:16 A.M. EDT (12:16 A.M. PDT). The second begins at 2:23 A.M. EDT May 23 (11:23 P.M. PDT May 22).

In both cases, the 8th-magnitude moon moves into Saturn's giant shadow slowly and disappears from view gradually. You won't see much dimming in the first couple of minutes after the start. During the next 15 minutes, however, Titan dims rapidly.

Titan shadow transits occur May 14/15 and May 30/31. Watch for the first hint of Titan's shadow on Saturn's globe at 1:26 A.M. EDT May 15 (10:26 P.M. PDT May 14). The second event begins at 12:32 A.M. EDT May 31 (9:32 P.M. PDT May 30).

With a diameter of 3,200 miles, Titan casts a long and wide shadow. The shadow appears as a slowly moving black dot on Saturn's globe. The shadow first appears on the planet's eastern limb. It looks elongated at the start but grows more circular as it approaches the disk's center. The shadow takes about 5 hours to cross the planet. For North American observers, Saturn sets before either of May's events ends.

Saturn's other moons all glow significantly fainter than Titan. A 4-inch telescope will show you a trio of 10th-magnitude moons: Rhea, Tethys, and Dione. You'll need a 6-inch scope to nab outer Iapetus, which remains east of Saturn all month and is no brighter than 11th magnitude. And 12th-magnitude Enceladus proves a challenge to see through an 8-inch telescope.



Ganymede briefly occults Europa before dawn May 11. This view shows the pair just before the event starts at 4:19 A.M. EDT. The occultation lasts just 7 minutes. *Astronomy*: Roen Kelly

At about the time Saturn dips low in the western sky, **Jupiter** pokes above the eastern horizon. The giant planet shines at magnitude –2.3 among the background stars of Capricornus. It far outshines every other object in this dim part of the sky. Jupiter will continue to brighten as it approaches opposition in mid-August.

Jupiter spans a healthy 40" in mid-May and displays plenty of atmospheric detail through almost any telescope. The best views will come in the hour or so before dawn, once Jupiter climbs higher in the southeast. You should notice immediately the planet's two equatorial belts — parallel dark bands arrayed on either side of a brighter equatorial zone. More subtle features, including the Great Red Spot if it's facing Earth, appear with patient viewing.

Even a quick glance at Jupiter through a telescope

Comet search

Comet Cardinal crosses cluster country

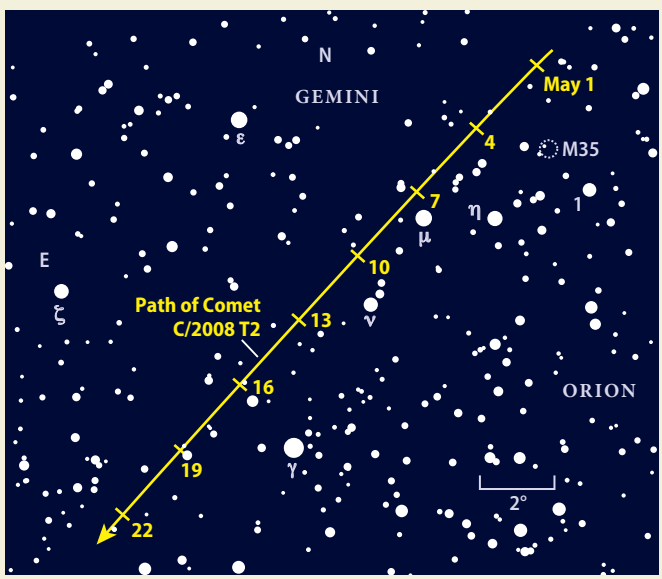
The May evening sky hosts one of the brighter comets of 2009. Comet C/2008 T2 (Cardinal) spends most of the month glowing at 9th magnitude among the background stars of Gemini. Light from the waxing Moon interferes with viewing the comet during May's first 10 days. Thereafter, this visitor from the distant Oort Cloud will be easier to see against the Milky Way background.

The comet also will be worth viewing in late April, particularly from the 22nd to the 24th. On those evenings, Cardinal lies less than 2° from Auriga's bright star cluster M37. The comet also passes within 2° of Gemini's bright open cluster M35 from May 2 to 4.

Although 9th magnitude may sound bright enough to see from a suburban backyard, the comet's light spreads out significantly, so it has a much lower surface brightness. If you head out to the country for a look, choose a location northwest of any city to avoid peering through the veil of light pollution.

May will provide the last chance for northern observers to get a good view of this dirty snowball. It grows fainter during the coming months and dives quickly into the southern sky.

University of Calgary researcher Robert Cardinal discovered this comet October 1 when it was floating above Polaris. The discovery came as part of the university's survey for unusual near-Earth asteroids.



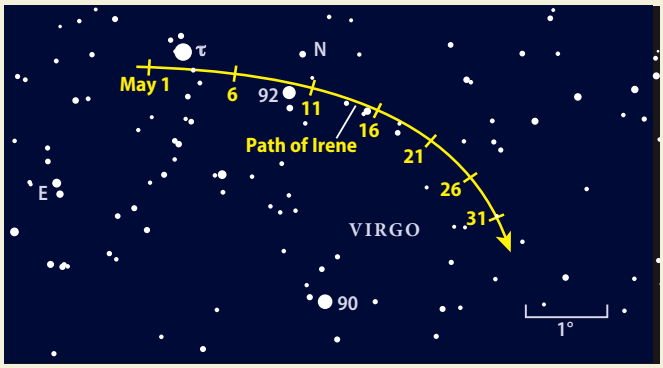
Comet C/2008 T2 (Cardinal) glows at 9th magnitude as it crosses Gemini during May. Look for it near the bright star cluster M35 early in the month. *Astronomy*: Roen Kelly

Discover peace in your lifetime

The main-belt asteroid 14 Irene slices through Virgo this month and appears at its best in late evening. To find this 112-mile-wide space rock, start with the 4th-magnitude star Tau (τ) Virginis. Tau lies a little closer to Spica than the halfway point to Arcturus.

On the evening of May 3, Irene lies just 12' south of Tau, sharing the field of view in a medium-power eyepiece. The asteroid then stands pretty much by itself until May 9, when it approaches close to 6th-magnitude 92 Virginis. A few field stars slightly fainter than Irene accompany 92 Vir.

English astronomer John Hind discovered this asteroid in 1851. A daughter of Zeus and Themis in Greek mythology, Irene is the personification of peace. Hind even suggested for the asteroid's symbol: "A dove carrying an olive-branch, with a star on its head." As you gaze on Irene this month, relish the fact that you have found peace.



Asteroid Irene calls Virgo home during May. It glows at 9th magnitude and should stand out through a small scope against a relatively sparse star field. *Astronomy:* Roen Kelly

will reveal up to four pinpoints of light near the planet that align with its equator. These moons — Io, Europa, Ganymede, and Callisto — shine at 5th and 6th magnitude. You could view them without optical aid if brilliant Jupiter didn't lie so close.

Like Saturn's Titan, Jupiter's moons regularly undergo transits, shadow transits, and eclipses as they orbit the planet. But Jupiter's moons provide a bonus because they frequently occult and eclipse each other. More than 30 of these so-called mutual events occur during May, although an observer at a single location can't see them all.

Ganymede takes part in a couple of nice events. It occults Io beginning at 5:35 A.M. EDT (2:35 A.M. PDT) May 4 and occults Europa at 4:19 A.M. EDT (1:19 A.M. PDT) May 11. Many more mutual events will occur later this year.

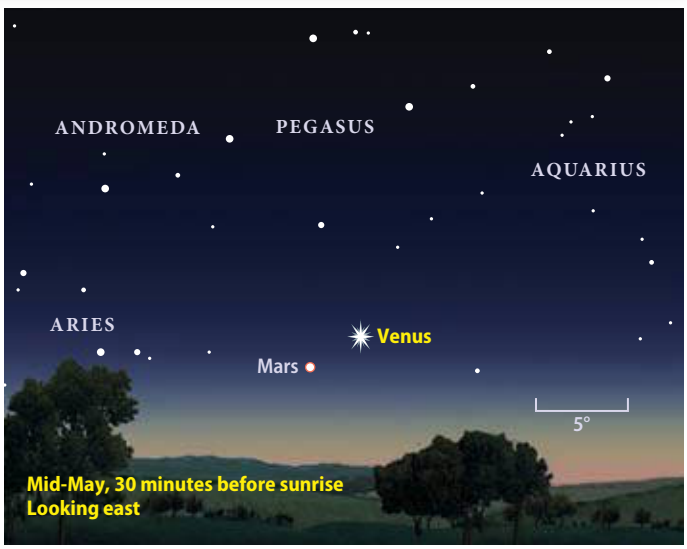
Astronomers call Jupiter's four bright moons the Galilean moons because Galileo first saw them. His observations proved that the moons orbit Jupiter. It was the first time anyone had seen a center of motion other than Earth, and it helped lay the groundwork for displacing Earth as the center of the cosmos.

Jupiter shares its corner of Capricornus with far dimmer **Neptune**. On May 25, Jupiter passes 0.4° south of the distant planet. Neptune glows at magnitude 7.9, making it a fairly easy binocular target. On May 20, Jupiter passes 0.1° south of the 5th-magnitude star Mu (μ) Capricorni. Neptune then lies less than 1° northeast of the pair.

Uranus resides well east of Jupiter and Neptune and rises more than an hour later. You can find Uranus in Pisces, some 5° south of the 5th-magnitude star Lambda (λ) Piscium. At magnitude 5.9, Uranus is easy to see through binoculars and is even visible with naked eyes under a dark sky. On the morning of May 19, a waning crescent Moon stands 5° above the planet.

Venus and Mars rise within 20 minutes of each other in mid-May. **Mars** glows at magnitude 1.2 and appears inconspicuous in the growing twilight. It will be several months before the Red Planet grows significantly brighter and large enough to show detail through a telescope.

Venus, on the other hand, dazzles. Gleaming at magnitude –4.7, it outshines every other object in the sky except the Sun and the Moon.



Venus climbs higher in the morning sky throughout May. Turn a telescope to the brilliant planet, and you can watch its phase change, just as Galileo did 400 years ago. *Astronomy:* Roen Kelly

You'll see rapid changes in Venus' appearance this month if you view it through a telescope. On May 1, Venus sports a 39"-diameter disk that is 25 percent illuminated. As May progresses, the disk's apparent diameter shrinks while the crescent phase waxes. By the 31st, the planet shows a disk that is 26" across and 46 percent lit.

Galileo saw Venus' changing phase when he viewed the planet 400 years ago. According to the then-dominant Earth-centered model, Venus should always appear as a thin crescent. The nearly half-lit Venus we see May 31 would be an impossibility, as would the gibbous and full phases on display later this year. Galileo watched all these changes and realized only a Sun-centered solar system made sense.

A nice spectacle awaits us the morning of May 21. A waning crescent Moon then stands 7° to Venus' upper left. Try to spot dimmer Mars as well. You may need binoculars to see the ruddy dot 6° directly below the Moon. By month's end, 5° separate Venus and Mars. The two will come noticeably closer to each other during June.

Experience Galileo's Italy

Walk in Galileo's footsteps in Rome, Florence, and other haunts of the great astronomer.

by William Sheehan

It isn't hard to find the influence of Galileo Galilei (1564–1642) on the history of astronomy. After all, he was the first to use a telescope to study the heavens systematically and objectively. He discovered the Moon's craggy mountains, Jupiter's four major satellites, and the phases of Venus.

But that's Galileo the scientist. Who was the man?

To find some clues, I went to Rome and Florence, where Galileo spent the prime of his life and ended up under house arrest for life after a disastrous encounter with the Roman Catholic Church. I decided to retrace the master's footsteps in Italy — to visit the places where he lived and worked in hopes of absorbing something of the spirit of the times in the 17th century when Galileo helped overturn what people thought they understood about the celestial realm.

Galileo Galilei (1564–1642) was born in Pisa and taught mathematics at Padua. He lived in Florence after 1610, where he wrote his greatest scientific works.
Science Museum Pictorial

Walking in Galileo's Footsteps
Astronomer and mathematician Galileo Galilei lived portions of his life in Pisa and Padua, but he considered himself a Florentine. His scientific achievements at first drew acclaim and privilege — but later brought him into conflict with Catholic doctrine and ended in humiliation and house arrest. Astronomy: Jay Smith
1609
Galileo presents a telescope to the Venetian Senate, which bestows on him life tenure at the University of Padua.
Padua
1592–1610
Chair of mathematics at University of Padua, Venetian Republic.
1610
Moves to Florence.
1588
Obtains lectureship in mathematics at University of Pisa.
Pisa
Florence
1616
On a visit to Rome, Galileo is cautioned not to "hold or defend" Copernican theory.
1631
Moves to Villa Il Gioiello in Arcetri near Florence.
1564
Born in Pisa.
Rome
1642
Dies in Arcetri.
1638
Inquisition grants permission for Galileo to move to Florence for health reasons. He is already completely blind.
1633
February: Arrives in Rome for trial by Inquisition of Rome.
June: Admits and abjures heretical beliefs at the Basilica Santa Maria sopra Minerva.
December: Returns to villa at Arcetri under house arrest for life.
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Roman rendezvous

Numerous people, such as the English poet John Milton, began to beat their way to Galileo's door even during the great man's lifetime. For logistical reasons — airport location — I started in Rome, where Galileo became a martyr for science. Lost among the strata and ruins of millennia, his footprints are barely traceable among those of the millions who have lived and died in the ancient city.

The Roman palaces of the Caesars and the temples of antiquity are melancholy ruins. Ransacked by the renaissance and baroque popes, they are mere shells gutted for raw materials to furnish monuments and tombs. Even the Caesars and popes who ruled here, whose power once reached out across the known world, are lost in the accumulated wreckage of the ages. Yet it is possible to find traces of Galileo's life within the walls of Vatican City, the sovereign state nested within Rome's boundaries.

St. Peter's Basilica is among the Vatican's most impressive monuments. Inside, I combed various tombs and eventually found the crypt of Paul III (1468–1549), the pope to whom Copernicus dedicated *De revolutionibus orbium coelestium* ("On the Revolutions of the Heavenly Spheres"). The 1543 treatise detailing a Sun-centered cosmos captured Galileo's imagination and ultimately contributed to his downfall.

Paul III rests on one side of the Cathedra Petri, an elaborate reliquary containing a wooden chair purported (falsely) to be the throne of St. Peter. On the opposite side of the Cathedra Petri molder the remains of a critical player in Galileo's life: Maffeo Barberini (1568–1644).

St. Peter's gilded interior is a treasure trove of art and architecture. In this photo, the church's dome illuminates the vaulted halls below. David J. Eicher

The grand columns in St. Peter's Piazza in Rome and the high dome of St. Peter's Basilica (background) convey the Vatican's power in Galileo's time. What the Florentine astronomer learned by looking through his crude telescope put him into a dangerous conflict with church doctrine. David J. Eicher

Barberini was once Galileo's friend and supporter. But after becoming Pope Urban VIII in 1623, he demanded Galileo's prosecution for allegedly upholding the Copernican theory, although really for disobedience to church authority in an age of absolutism.

Urban was not a lovable character. When he died, the citizens of Rome, who had long sweated under the yoke of financing his construction projects and wars, expressed their gratitude to him by toppling one of his busts.

In the Vatican Museums en route to the Sistine Chapel, I couldn't resist poking my head through some of the open windows into the gardens. I thought of the birds that Urban had ordered killed so they wouldn't interfere with his sleep.

William Sheehan *is an author, psychiatrist, and amateur astronomer in Willmar, Minnesota. His latest book is* A Passion for Planets, *being published by Springer during the International Year of Astronomy 2009.*

Galileo, heretic

While within the walls of Vatican City, I took a long look at its first observatory, often called the Tower of the Winds. Established by Gregory XI, pope from 1370 to 1378, the tower stands atop the Vatican Secret Archives where an infamous document was stored that would later figure in Galileo's downfall.

Galileo had come to Rome in 1611 and triumphantly demonstrated the telescope to the Jesuits of the Collegio Romano, who after months of trying had finally confirmed his observations. He returned in 1616 to meet with Cardinal Bellarmine, who warned him not to "hold or defend" the literal truth of the Copernican system.

In private, Bellarmine and the ruling prince of Rome, Pope Paul V, were inclined to declare Copernicanism heretical. However, Cardinal Caetani and Barberini dissuaded them. When Barberini was elected pope, Galileo anticipated a new golden era for liberal Catholics.

After meeting with Urban, Galileo thought he had received permission to write a book, *Dialogue Concerning the Two Chief World Systems* (1632), as long as he didn't hold or defend the Copernican system. In the book, three characters debate the merits of the Sun-centered Copernican system versus that of the traditional Earth-centered cosmos.

But Galileo miscalculated by presenting Pope Urban's own arguments in the mouth of a dimwitted character named Simplicio. The offended pope unleashed the Inquisition of Rome, which called Galileo to the Vatican for trial in 1633. After waiting 2 months in the Villa Medici, the astronomer was finally questioned by the Inquisitors.

Galileo was prosecuted on the basis of a questionable injunction retrieved from the Vatican Secret Archives. Dating to 1616, the document was neither signed nor notarized. It claimed Galileo had agreed not to hold or defend the Copernican theory or to discuss it, as he clearly

The Sistine Hall is part of the Vatican Library, one of the oldest collections of books and manuscripts in the world. Among its holdings are the extensive records of Galileo's prosecution for heresy. David J. Eicher

The Jesuit Collegio Romano, or College of Rome, was a major center for scientific research in Galileo's day. In 1611, scholars at the college confirmed the accuracy of what Galileo saw through his spyglass. William Sheehan

had in *Dialogue*. The Inquisition condemned Galileo on "vehement suspicion of heresy." He remained under house arrest until his death in 1642.

The persecution of Galileo was not without precedent. A statue stands in the Campo del Fiore in Rome, where in 1600 Giordano Bruno was burned at the stake for teaching heretical views such as the Copernican doctrine.

Young Galileo's Italy

Rome was merely the stage on which Galileo's late downfall played out. He spent most of his years in Pisa and Florence, in the northern province of Tuscany, and in Padua, then part of the Venetian Republic.

Galileo was born in Pisa February 15, 1564, and later pursued his education at the University of Pisa. Even then, the scientist in Galileo was blooming. He reportedly began to consider the laws that govern the swing of a pendulum while observing the motions of a swinging chandelier in the town's cathedral.

However, Galileo ran into the opposition of conservative scholars in Pisa. He moved on to Padua, where he lectured in mathematics and made all the telescopic observations of the Moon and Jupiter described in his 1610 book, *Sidereus Nuncius* ("Sidereal Messenger").

^ Italian philosopher Giordano Bruno was a proponent of Copernicus' Sun-centered theory. This relief on a statue in the Campo del Fiore, Rome, depicts Bruno's trial before the Roman Inquisition. He was burned at the stake for heresy February 17, 1600. William Sheehan

< Galileo's onetime supporter, Cardinal Maffeo Barberini, was elected Pope Urban VIII in 1623. A decade later, he unleashed the Inquisition on the astronomer. Linda Hall Library of Science, Engineering, and Technology

Galileo later recalled the 18 years in Padua as the happiest in his life. But he was restlessly ambitious, and also at heart a Florentine. He had spent his teenage years in that Tuscan city and, in September 1610, returned to stay there after being appointed Philosopher and Mathematician to the Grand Duke of Tuscany.

In Florence, one can easily imagine Galileo strolling the city's bustling streets, perhaps walking through the Piazza della Signoria with its arrogant equestrian statue of the Grand Duke Cosimo I de' Medici. One can picture him climbing the steps of the Palazzo Vecchio, the town hall of Florence, to demonstrate the telescope he offered in March 1610 as a gift to his patron Cosimo II de' Medici (grandson of Cosimo I).

The telescope and one of Galileo's fingers — still pointing heavenward after all these years — are preserved in Florence's Institute and Museum of the History of Science. The lens, cracked in Galileo's lifetime, is carefully protected behind glass at the museum. The sight of it sent more shivers down my spine than the cumulative effect of all the tombs of the popes in St. Peter's. It was with such a lens that Galileo made the most important series of astronomical discoveries ever.

In Florence, Galileo continued to produce important scientific works. At the

^ The vineyards and meadows of the Tuscan countryside on the outskirts of Florence served as the backdrop of Galileo's final years. In 1631, he moved to the Villa Il Gioiello (inset) on the hill of Arcetri. William Sheehan

palatial Villa L'Ombrellino, where he lived from 1617 until 1631, he wrote *Il Saggiatore* ("The Assayer"), a treatise on mathematics and physics, and the *Dialogue* that led to his persecution.

Into the Tuscan hills

Galileo doubtless journeyed often to the outskirts of Florence to the Convent of San Matteo where his two daughters by his Venetian mistress Marina Gamba were cloistered. Virginia, who took vows as Sister Maria Celeste, was the eldest and his favorite. The sister is the heroine of Dava Sobel's bestselling book *Galileo's Daughter*, which poignantly reveals the depth of the bond between father and daughter. Sister Maria Celeste baked her father cakes and starched the broad white collars in which Sustermans, the official painter to the Medici court, would later paint him. (Gaze upon the original in Florence's Uffizi Gallery.)

> A bust of Galileo stares out from one wall of the Villa Il Gioiello, "the jewel." William Sheehan

In 1631, Galileo, now 67 years old, moved to the Villa Il Gioiello, "the jewel," to be closer to his daughters. From the villa, set on the hill of Arcetri south of the city, Galileo could see the convent. It's on the street below the tower called the Torre del Gallo, reputed to be the place where Galileo conducted experiments and observations.

The trip to Arcetri is unforgettable. One route begins at the ramparts of the Fort Belvedere. Then one proceeds into the countryside along the narrow and enchanting Via San Leonardo between enclosed walls and groups of fine houses.

The route also winds past the Osservatorio Astrofisico di Arcetri (the Arcetri Astrophysical Observatory), which still conducts astronomical research today. It is just a stone's throw from Galileo's villa and easily visible, below the Torre del Gallo, on the hills in the near distance.

The Convent of San Matteo is just down the street from Il Gioiello, where admirers of *Galileo's Daughter* would enjoy visiting. Unfortunately, fire almost completely destroyed the original structure. Only the dining area, or refectory, remains of the walls within which Sister Maria Celeste spent her life while her father explored the sky. Don't miss the

< This dining area is all that remains of the original Convent of San Matteo, lifelong residence of Galileo's daughters Virginia (Sister Maria Celeste) and Livia (Sister Arcangela). William Sheehan

< Sister Maria Celeste lived at the Convent of San Matteo in Arcetri, where a modern stained-glass window commemorates the close relationship she had with her father, Galileo. William Sheehan

modern stained glass in the convent chapel depicting Galileo and his daughter.

The end days

At Il Gioiello, Galileo watched the candle burn out of his last days as a prisoner under house arrest. The untimely death of his favorite daughter in 1634 — a blow from which Galileo never really recovered — came the year after his prosecution in Rome. The same year, suffering from a painful hernia, he applied to the Inquisition to be allowed to move to Florence to be closer to his doctors. The church officials refused his petition and warned him that any further requests would land him in prison.

Alone, depressed, and in constant ill health, he worked to complete his masterpiece, *Discourse on the Two New Sciences*, which laid the foundations of modern physics. The book was smuggled out of Italy and published in 1636 in the Netherlands.

Galileo made his last astronomical discovery — the Moon's slight wobble, or "libration" — in July 1637. At the time he was able to see only a bit with his left eye. Months later, he went completely blind.

At last, in 1638, the Roman authorities showed mercy to Galileo. He received permission to move for several months to his house in Florence so that he could more easily visit his doctors. After this brief interlude, he was back at Il Gioiello in September 1638 when John Milton, a 30-year-old poet from England, visited him there, "in darkness, and with dangers compassed round."

Galileo died January 8, 1642. At first — because Urban continued his persecution of Galileo even in death — the astronomer was not allowed burial in the main church in Florence. So he rested for more than a century in the small convent chapel in Florence before finally being reinterred in a grand tomb in the main church, the Basilica di Santa Croce. Galileo's resting place is right across from the tomb of Michelangelo.

> Pope Urban VIII continued his persecution of Galileo even in death.

Grand as his baroque tomb is, don't look for Galileo's monument there. Rather, gaze at his heavens. Look at the Moon, at Jupiter with its ever-revolving satellites, at Venus whose phases he first saw, at the Milky Way with its innumerable stars. These celestial objects will carry Galileo's name to future generations.

For another testament to how radically Galileo changed our perception of the celestial realm, seek out the Assumption of the Blessed Virgin. It's a work by Galileo's Florentine friend, the painter Cigoli. The fresco remains today at one of the most prominent religious sites in Rome, the Pauline Chapel of the Basilica di Santa Maria Maggiore.

Pazzi Chapel (left), part of the Monumental Complex of Santa Croce, Florence, was Galileo's first burial site. Pope Urban VIII would not allow Galileo to be buried in the main church, the Basilica di Santa Croce (right). He was reinterred in the basilica a century later. William Sheehan

Galileo's influence extended into art, as shown in this 1612 portrait, Assumption of the Blessed Virgin, by the painter Cigoli. The Moon she stands on is the craggy "imperfect" Moon of Galileo, not the smooth and pure Moon seen in other portraits of Mary. William Sheehan

In his last work, Cigoli painted a portrait of the Blessed Virgin unlike any other. Other portraits portrayed Mary standing on a perfectly smooth and unblemished representation of the Moon. Earth's luminous satellite, after all, was a symbol of purity — just like Mary. But Cigoli's 1612 painting shows the Virgin's feet upon an orb with craggy craters and mountains — Galileo's Moon.

On my last morning in Florence, I rose before dawn to catch a cab to the airport. On the way, Galileo's Moon played hide-and-seek with the clouds. I could not help thinking of what the 19th-century French astronomy writer Flammarion wrote when Florentine astronomer Giovanni Battista Donati placed one of Galileo's telescopes in his hands. "After sunset I recaptured the spirit of the Florentine astronomer on one of the beautiful Italian terraces just as the stars were coming out," Flammarion recalled. "With feverish impatience I turned this marvelous tube toward the new worlds that he had discovered in the heavens. I recalled that he had shown these sights to those who were incredulous; he still shows them to us today from his grave."

Read an interview with author William Sheehan at www.Astronomy.com/toc.

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

Could Io empty and collapse?

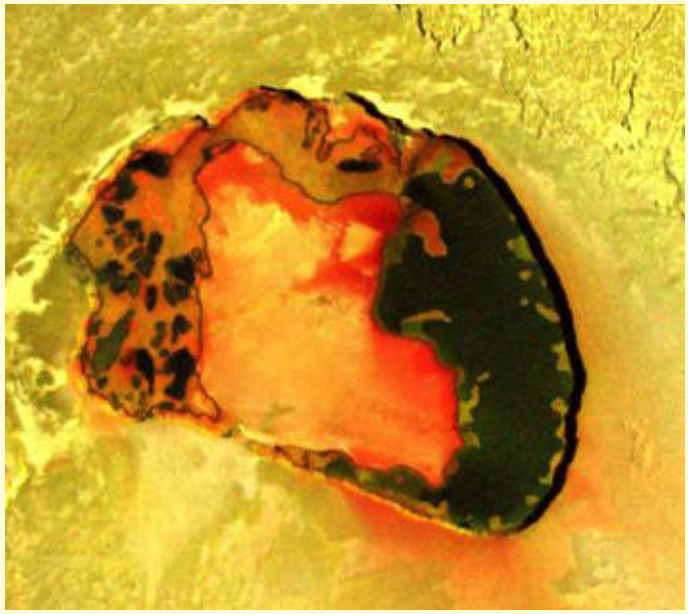
Q: If Io continues to erupt at the fast rate it does now, could all of the moon's insides end up on the surface, causing it to collapse onto itself and start the process all over again? — **Tony Royal,** Daytona Beach, Florida

A: Jupiter's moon Io does erupt at an extremely fast rate, constantly disgorging sulfur dioxide gas, liquid sulfur, and molten rock. However, **Io does not erupt a large enough volume of material fast enough to hollow out its interior and then collapse.**

Io erupts about 120 cubic miles (500 cubic kilometers) of material per year. That's an incredibly high rate if you consider that Earth erupts "only" about 1 cubic mile (4 cubic km) of molten rock per year.

The volume of lava erupted on Io must be extremely high to bury impact craters relatively soon after they form. We know this occurs because no impact craters are discernable on the moon's surface. As the eruptions pile material onto the surface, the weight compresses the crust and causes it to deflate and subside.

Over the 4.5-billion-year lifetime of the solar system, Io has probably erupted and recycled much of its interior many times. But on a global scale, it is a slow process. Even given the high rate of volcanism, all annual volcanic activity on Io adds up to far less than 1 percent of the moon's total volume — only about 1 part in 600,000 per year. — **Ashley Davies,** Jet Propulsion Laboratory, Pasadena, California



NASA/JPL/University of Arizona

Tupan Patera, shown in this false-color Galileo spacecraft image, is one of numerous volcanic craters on Jupiter's moon Io. The cliffs at the edge of the crater are about 3,000 feet (915 meters) tall.

CELESTIAL CENSUS

Q: How many black holes have astronomers discovered in our Milky Way Galaxy? How do they find a black hole? — **Sayed Alawi,** Anaheim, California

A: To date, astronomers have found 19 confirmed black holes and an additional 18 potential black holes, for a total of 37. All but one of the 37 lie in binary (double star) systems, each in the range from 5 to 10 times the Sun's mass. Astronomers have also identified a supermassive black hole at the galaxy's center containing about 4 million times the Sun's mass.

In binary systems, a black hole and a star orbit each other. The black hole's powerful gravity strips gas from its companion. As the gas accelerates toward the black hole and heats to millions of degrees, it gives off X rays. Astronomers find the black holes by looking for their characteristic X-ray emissions.

To confirm the black hole's existence, astronomers track the companion star's orbital motions. Knowing the star's orbital speed makes it possible to calculate the mass of the companion black hole. — **Tod Strohmayer,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

STELLAR ZOOLOGY

Q: What is a Wolf-Rayet star? — **David Camfield,** Amarillo, Texas

A: A Wolf-Rayet star is a type of massive star. They typically weigh in at 20 to 50 times the mass of our Sun. "Wolf-Rayet" comes from the names of two astronomers, Charles Wolf and Georges Rayet of the Paris Observatory, who discovered them.

In 1867, Wolf and Rayet observed an unusual pattern in the wavelengths of light emitted by certain stars. The pattern, or spectrum, indicated emission of light from helium. No one had seen this before.

Later, astronomers found the reason: A Wolf-Rayet star loses its outer hydrogen layers late in its evolution. This exposes elements heavier than hydrogen that are produced in the star's core, including helium, carbon, oxygen, and nitrogen.

Wolf-Rayet stars are also notable for their powerful outflows, or stellar winds. These flows carry mass off the stars' surfaces at speeds of up to 4.5 million mph (7.3 million km/h). In addition, Wolf-Rayet stars are extraordinarily hot, with surface temperatures up to 90,000° Fahrenheit (50,000° Celsius).

Wolf-Rayet stars last for a relatively short time, typically less than a million years. Due to their immense masses, these stellar giants eventually end in supernova explosions that form neutron stars or black holes. **— Cornelia C. Lang and Allison Mercer,** University of Iowa, Iowa City

COSMIC RULER

Q: What is a parsec? Why do scientists use this unit instead of light-years? — Robert Garver, Sanford, Florida

A: The parsec is a unit for measuring vast astronomical distances based on the parallax effect — the apparent motion of a star across the more distant stellar background when viewed from Earth 6 months apart. One parsec equals 3.26 light-years, or the distance light travels in 3.26 years.

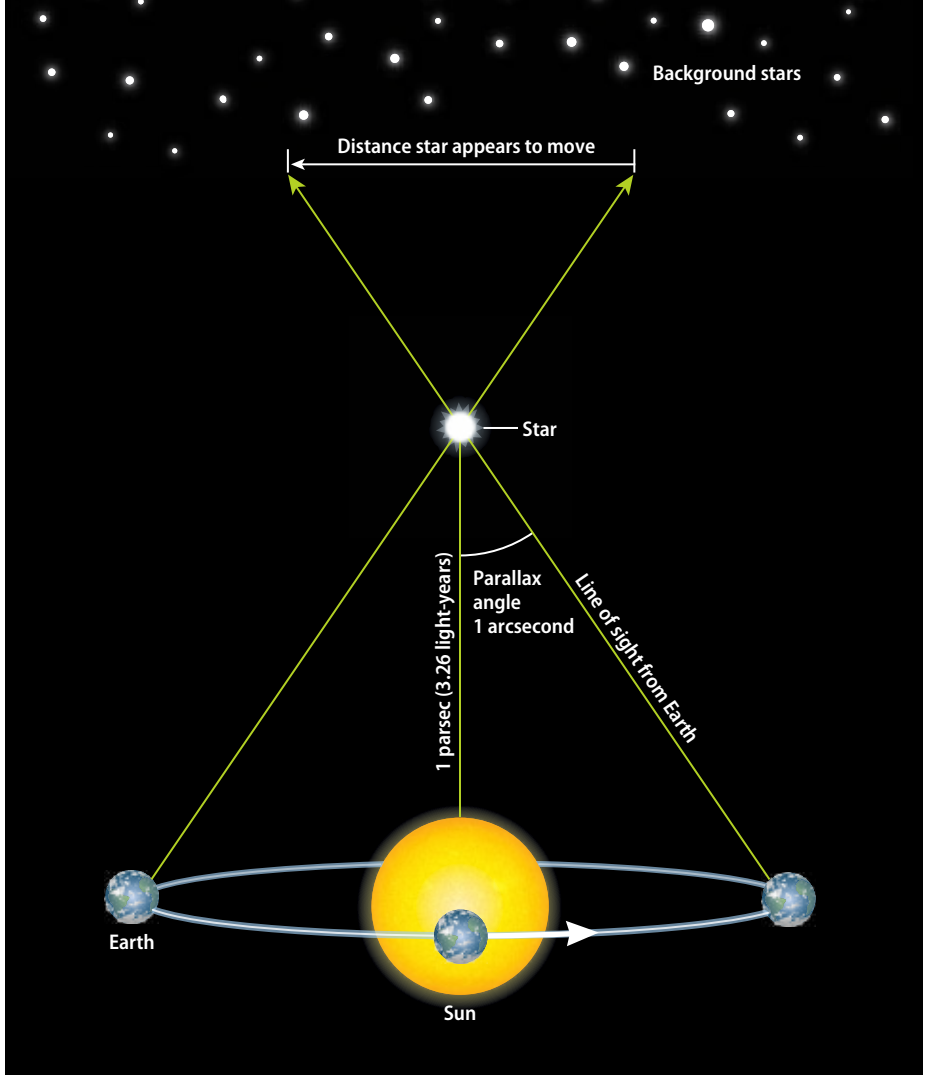
To experience the parallax effect, hold your hand straight out in front of you, giving the "thumbs up" sign. Now quickly blink between your left and right eye: Your thumb seems to jump back and forth against the background.

In the 19th century, astronomers found they could use stellar parallax to determine a star's distance from Earth. It's a process similar to triangulation: Two observations of the star taken 6 months apart provide two different sightlines, just as when you blink your eyes back and forth. The star, like your thumb, will appear to move with respect to more distant background stars when viewed from opposite points along Earth's orbit.

The parallax angle is one-half the angle between the two sightlines to the star. A star with a parallax angle of 1 arcsecond (1/3600 of a degree) would be 1 parsec ("parallax second") from Earth.

Astronomers often use the parsec instead of the light-year because it's a convenient system based on powers of 10. Larger parsec units include the kiloparsec (1,000 parsecs, or 3,260 light-years) and the megaparsec (1 million parsecs, or 3,260,000 light-years.) These large units provide good round-number approximations of vast astronomical distances. **— Geoff Chester,** U.S. Naval Observatory, Washington, D.C.

What's the difference between open and globular star clusters? To find out, go to www.Astronomy.com/toc.



Stellar parallax allows astronomers to measure the distance to stars using geometry. A star 1 parsec (3.26 light-years) from Earth has a parallax angle of 1 arcsecond. *Astronomy:* Roen Kelly

DEEP FREEZE

Q: With temperatures being so low in space, why don't the gases condense into liquids or freeze as they do here on Earth? — James Bradley, Buford, Georgia

A: The gas in deep space is known as the interstellar medium (ISM) because it consists of the gas residing between the stars. **Interstellar gas doesn't condense into a liquid or freeze into a solid because the density of the gas is too low.**

The ISM's density is around one gas atom per cubic inch. By comparison, a cubic inch of Earth's atmosphere contains an average of a trillion billion particles — the number 1 followed by 21 zeros.

In Earth's relatively dense atmosphere, water vapor can condense into stable droplets because the ambient pressure is high enough to counteract the droplets' tendency to evaporate.

In space, however, the extremely low pressure doesn't allow droplets to "keep it together." If a water droplet were to form, it would instantly vaporize.

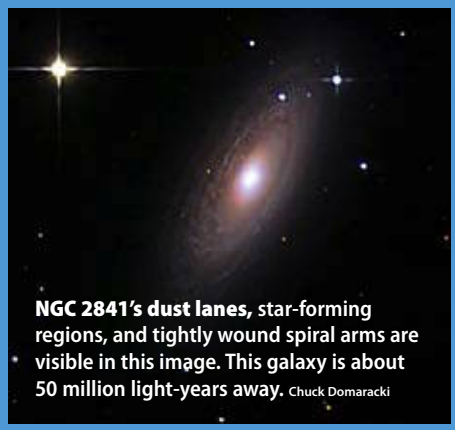
Solids are held together by much stronger forces than liquids, so it's possible for them to remain stable even in space. However, in space the low pressure makes it hard for sufficient gas particles to come together to form a stable solid. The gases need a surface to stick on.

Interstellar gas clouds contain tiny particles of dust forged in the dense atmospheres of nearby stars. Gas can freeze onto these particles, creating a thin coating of ice. **— Eli Dwek,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Explore the Great Bear's galaxies

Break out your medium-sized telescope and search Ursa Major's extragalactic treasures. **by Steve Coe**



NGC 2841's dust lanes, star-forming regions, and tightly wound spiral arms are visible in this image. This galaxy is about 50 million light-years away. Chuck Domaracki

Many beginning observers in the Northern Hemisphere quickly learn that the prominent asterism the Big Dipper belongs to Ursa Major the Great Bear. Advanced observers return to the familiar Bear because of its plethora of galaxies. This section of the sky is far from the Milky Way band, so there are few star clusters and nebulae. Now, let's set up the telescope and enjoy some galaxies. I performed all observations with a 13-inch f/5.6 Newtonian telescope unless otherwise noted.

The Bear's front quarters

Our first stop is near Ursa Major's front legs. At 135x, **NGC 2681** appears luminous and fairly large. It's bright in the middle with a stellar nucleus. The spiral galaxy is a little elongated (about 1.2 times longer than it is wide). Its position angle (p.a.) is roughly 45°, which means the galaxy aligns northeast to southwest.

Due to a chance alignment, there's a foreground double star on the spiral galaxy's northwest edge. When observing NGC 2681 using an 11-inch Schmidt-Cassegrain telescope (SCT) at 125x from a better site, I saw a hint of spiral arms when using averted vision.

Moving some 5.5° east, spiral galaxy **NGC 2841** is aglow and somewhat large with a bright nucleus. At 135x, several foreground stars line up with the southern arm. This galaxy is about 3 times longer than it is wide. At powers higher than 135x, the arms are faint, but the stellar nucleus stands out. At 220x, the nucleus seems almost stellar, and the arms have a "mottled" texture. In the spiral arms of galaxies, this blotchy structure results from the presence of star clusters and nebulae so far away from us that we cannot resolve them using a modest telescope. One reason astronomers build large professional telescopes is to resolve these clusters into stars and use spectrographs to determine the objects' chemical and physical characteristics, such as temperature and pressure.

Next, connect Upsilon (υ) Ursae Majoris to Omicron (o) UMa. About halfway between them sits elliptical galaxy **NGC 2768**. It's luminous, large, and glows brightly in the middle. At 100x, NGC 2768 is elongated (3x1) and aligns exactly east-west. The galactic core is also elongated, about 1.8x1, in the same orientation as the galaxy.

The Bear's back

Moving some 10° north, you'll find **NGC 2787**, which appears big and round and glows in the middle. I see two faint foreground stars at 100x. In this galaxy's NGC description, it has an "r," which means it's somewhat resolved. At 165x, this object looks to me like a globular cluster, hence the illusion of partial resolvability.

M81 (NGC 3031) is a well-known and bright spiral galaxy, with a luminous middle. This large object is also known as Bode's Galaxy. At 100x, M81 is elongated 2.5x1. I've heard of observers who can pick out the spiral structure, but even at the best of sites I've never seen that in M81. At medium powers, I see a hazy disk with a blazing core that is bright enough to see in the finder scope. When I raise the power to 220x, I can see a bright stellar nucleus and two 11th-magnitude foreground stars in the south arm. M81's arms are somewhat mottled.

Just 0.6° north lies **M82** (NGC 3034), a large and radiant irregular galaxy. It's

The barred spiral M109 (NGC 3992) is located some 46 million light-years away from Earth. This image shows detail within the spiral arms and central bar. R. Jay GaBany

Steve Coe *has been an avid observer in Arizona for more than 30 years.*

NGC 3184, a face-on spiral galaxy, sits at least 25 million light-years away from us. About 10 years ago, astronomers observed a supernova in this brilliant galaxy. Adam Block/NOAO/AURA/NSF

roughly 4 times as long as it is wide. M82 is somewhat brighter in the middle at 165x. There are several foreground stars, and the galaxy's entire body appears mottled. Dark lanes cut the galaxy into three almost equal parts. At 220x, the dark lanes are more prominent, and the brightest section of the galaxy is about one-third of the way in from the northeast tip. This entire bizarre galaxy looks much more mottled at high power.

NGC 3077 also lies near M81, about 1° to the southeast. This luminous irregular galaxy is rather large. It's elongated (about 1.5x1) and much brighter in its middle at 165x. This is one of UMa's more starry fields. At 220x, NGC 3077 has a stellar nucleus, which direct vision holds steady. In the NGC, William Herschel (1738–1822) noted "R w ray," which means "round with ray (extension)." Using averted vision, you can see a bright extension of the galaxy to the northeast.

The Bear's body

Let's now move to the asterism itself: the Dipper. You'll find **M108** (NGC 3556) just south of the bowl. While most Messier objects are visible through a big finder scope, I can't see M108 in my 11x80 finder on a mediocre night. It seems to be one of the lower-surface-brightness objects on the Messier list. It appears fairly bright, broad, and elongated (3x1) at 100x. This galaxy has a bright stellar nucleus. M108 shows almost smooth arms with little mottling. Moving up to 220x shows no new detail in the arms, but the core now looks like the smallest bright core I have ever seen at fairly high power.

Moving some 4° northeast, **NGC 3610** at 165x is aglow with a bright middle. It's rather large and round. In moments of good seeing, I can see a small, almost stellar nucleus. An extremely faint companion, PGC 213808, is 4' away in p.a. 230°; I can just pick it out with averted vision. Using an 11-inch SCT at a much better location, I see NGC 3610 as slightly elongated (1.2x1).

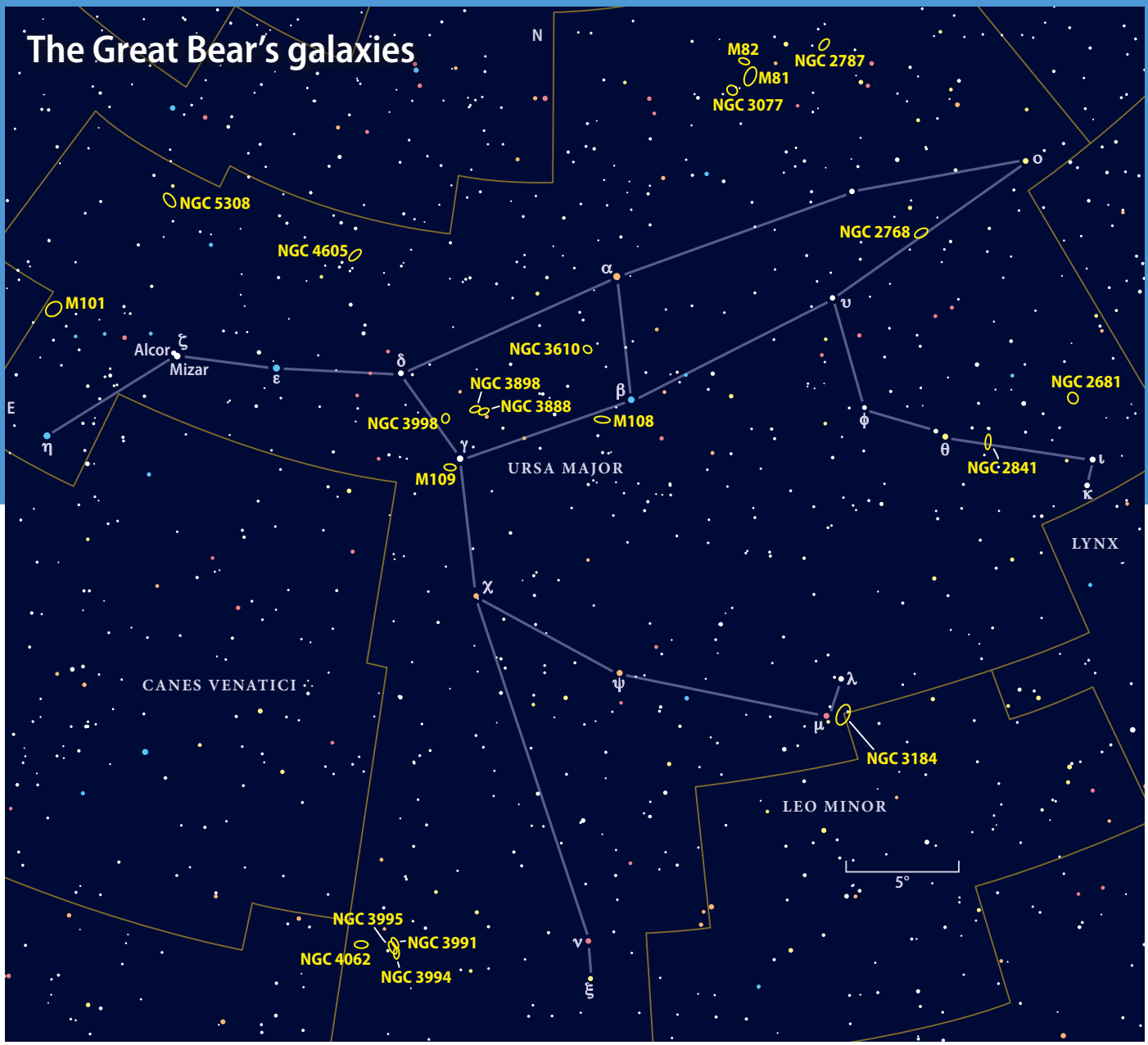
NGC 3888 and **NGC 3898** form a galaxy pair inside the Dipper. The galaxies are about 5' apart. At 135x, they both are somewhat bright (with middles aglow), quite small, and elongated in p.a. 60°.

Our next stop is **NGC 3998**. At 135x, it is somewhat luminous (brighter in the middle) and large. It is a little elongated (1.2x1). NGC 3998 has an extremely faint companion, MGC +09–20–046 that I can see only with averted vision and a hood over my head to block out stray light. If you're looking for a challenge, this is one.

About 1° east of Gamma (γ) UMa, just outside the Dipper's bowl, lies **M109** (NGC 3992). At 135x, it's fairly bright, big, and elongated in p.a. 90° (east-west). This galaxy has a radiant nucleus. M109's outer arms sparkle with mottling and three foreground stars. At 165x, this galaxy undergoes an interesting shape change. With direct vision, it appears elongated with a hint of barred spiral structure; with averted vision, it appears almost round with no spiral structure.

The Bear's hind legs

Less than 1° to the west of Lambda (λ) UMa sits **NGC 3184**, a fairly luminous, somewhat large, and round spiral galaxy. It has a bright middle at 165x. An 11th-magnitude foreground star is on the north side. In moments of good seeing, the arms appear mottled. I observed with Jeannie Clark and her 20-inch f/5 Newtonian reflector at the Texas Star Party a



Find your way around Ursa Major the Great Bear using this star chart. On the chart, you can locate all galaxies discussed in this article. *Astronomy*: Roen Kelly

few years ago. With that scope, this galaxy's middle appeared gradually brighter. I saw spiral structure, but it's easier to see with averted vision because the fine detail has low surface brightness. NGC 3184's core is elongated.

Next let's head to a small galaxy group, NGC 3991/3994/3995. **NGC 3991** is the northernmost galaxy. At 150x, it's faint, small, has a brighter middle, and is elongated 1.8x1 in p.a. 30°. **NGC 3994** is dim, small (with a luminous middle), and elongated 1.5x1 in p.a. 30°. **NGC 3995** appears quite faint, rather little, and brighter in the middle. It is twice as long as it is wide in p.a. 30°. I observed this group from a dark site in the Arizona desert about 100 miles from central Phoenix. All three galaxies fit in the field of view at 100x. Strangely, all of these galaxies have a p.a. of 30°.

Some 2° southeast is **NGC 4062**, a radiant spiral galaxy that is large and gradually brighter in the middle. At 135x with averted vision, I see a bright stellar nucleus. To me, it appears about 3 times longer than it is wide. A wide foreground double star sits at the west end.

The Bear's tail

NGC 4605 is a nice edge-on spiral galaxy. If you like "flat" galaxies, this one certainly fits the bill. At 150x, it appears bright, somewhat big, and gradually more luminous in the middle. NGC 4605 is elongated — about 4 times longer than wide.

NGC 5308 is pretty bright, pretty small, and roughly 2.5 times longer than it is wide. I can see a somewhat brighter middle with a luminous nucleus. Because NGC 5308 is a moderately high-surface-brightness galaxy, using averted vision shows NGC 5308's faint outer sections and makes the galaxy appear longer and a little thicker. Increasing power to 330x and using averted vision shows an almost stellar nucleus with a hint of a dark lane.

> The grand design spiral galaxy M101 (NGC 5457) is one of the most spectacular objects in the sky. It sits about 25 million light-years from Earth. The galaxy is huge: some 170,000 light-years across. Our Milky Way's diameter is about half that. Dean Rowe

The edge-on spiral M108 (NGC 3556) shows prominent dust lanes. No central bulge or core is visible in this galaxy. M108 is roughly 45 million light-years away. Bob and Janice Fera

NGC 4605 is an elongated spiral galaxy located roughly 20 million light-years away. In this image, you can see dust lanes blocking the bright central core. Jack Newton

Locate great galaxies

Name	Type	Right Ascension	Declination	Apparent Magnitude	Size
NGC 2681	Spiral	08h53.5m	51°18.8'	10.2	3.6' by 3.3'
NGC 2768	Elliptical	09h11.6m	60°02.2'	9.9	6.4' by 3.0'
NGC 2787	Spiral	09h19.3m	69°12.2'	10.8	3.1' by 1.8'
NGC 2841	Spiral	09h22.0m	50°58.6'	9.3	8.1' by 3.5'
M81	Spiral	09h55.6m	69°04.0'	6.9	24.9' by 11.5'
M82	Irregular	09h55.9m	69°40.8'	8.4	11.2' by 4.3'
NGC 3077	Irregular	10h03.3m	68°44.1'	9.9	5.2' by 4.7'
NGC 3184	Spiral	10h18.3m	41°25.4'	9.8	7.4' by 6.9'
M108	Spiral	11h11.5m	55°40.4'	10.1	8.6' by 2.4'
NGC 3610	Elliptical	11h18.4m	58°47.2'	10.8	2.7' by 2.3'
NGC 3888	Spiral	11h47.6m	55°58.0'	12.0	1.8' by 1.4'
NGC 3898	Spiral	11h49.3m	56°05.0'	10.8	4.4' by 2.6'
NGC 3991	Irregular	11h57.5m	32°20.1'	13.0	1.3' by 0.3'
NGC 3994	Spiral	11h57.6m	32°16.6'	12.7	0.9' by 0.5'
M109	Spiral	11h57.6m	53°22.4'	9.8	7.5' by 4.4'
NGC 3995	Spiral	11h57.7m	32°17.6'	12.6	2.6' by 0.9'
NGC 3998	Spiral	11h57.9m	55°27.2'	11.6	2.9' by 2.4'
NGC 4062	Spiral	12h04.1m	31°53.7'	11.2	4.0' by 1.7'
NGC 4605	Spiral	12h40.0m	61°36.5'	10.1	5.9' by 2.4'
NGC 5308	Spiral	13h47.0m	60°58.4'	11.3	3.6' by 0.7'
M101	Spiral	14h03.2m	54°21.0'	7.7	28.8' by 26.9'

Right ascension and Declination are given in epoch 2000.0 coordinates.

Let's move to **M101** (NGC 5457), which is one of my favorite galaxies to view. Not only does this face-on galaxy show spiral structure on a good night, but there are also several bright clusters and nebulae in the spiral arms that stand out in a modest scope.

At 100x, I see M101 as brilliant, large, irregularly round, and with a luminous middle. There's an almost stellar nucleus within the core at 165x. At most observing sites, an 11x80 finder shows a large blurry spot at M101's location. On an evening I rated 9 out of 10 for transparency, I saw the spiral structure easily at 100x. An ultra-high-contrast filter provides an excellent view of the spiral arms shimmering from HII regions.

I have observed this galaxy often, and it, like most face-on spirals, shows fine detail only on nights when the seeing and transparency are both excellent.

The great galaxy search

Ursa Major holds a galactic bounty, from brilliant spirals to fairly faint irregulars, and everything in between. Bring your moderate-sized telescope and head to a dark site on a clear night to explore the Great Bear's many diverse galaxies.

Visit www.Astronomy.com/toc for an Ursa Major galaxy observing account by Senior Editor Michael E. Bakich.

25 top telescopes for starry nights

Set up one of these high-quality instruments, and you'll be in observing heaven. **by Phil Harrington**

Tony and Daphne Hallas

Celestron C6-RGT

You and I are living in the golden age of amateur astronomy, especially when it comes to telescopes. Never before have hobbyists had such a wide variety of instruments from which to choose.

In fact, there are so many top-quality models available that sorting through them and choosing just one can be tough. To help guide you along the way, I've compiled a list of 25 of today's best telescopes. I based my choices on design, versatility, quality, price, and availability.

Some of the instruments listed here are readily available through retail dealers, while others are special-order items that may take the manufacturer some time to build. And although there is no one perfect telescope for everyone, these 25 all provide one important trait: owner satisfaction.

Refractors

Celestron C6-RGT

The 6-inch f/8 C6-RGT is one of the largest achromatic refractors sold off the shelf today. A telescope like this is great for planet and double-star enthusiasts who dabble in deep-sky observing. The heart of this scope, a two-element achromatic objective lens, is large enough to resolve sub-arcminute doubles and pull in stars as faint as 14th magnitude. Perched atop Celestron's highly acclaimed CG-5 computerized German equatorial mount, the C6-RGT can steer itself to thousands of targets within its range.

$1,099

Coronado Personal Solar Telescope

Coronado Personal Solar Telescope (PST)

This little 1.6-inch f/10 Hydrogen-alpha solar refractor allows anyone to observe prominences and the chromosphere. The quality construction, including an aluminum tube, fine-adjustment focuser, and integrated finder scope, belies the PST's amazingly low price. A 20mm Kellner eyepiece comes with the telescope, but no mount. However, the PST is light enough that most camera tripods can support it.

$499

Orion SkyView Pro EON 80ED

Orion was first to introduce budget apochromatic refractors. That tradition continues with Orion's latest generation of economically affordable apos, called EONs. The 3.1-inch f/6.25 EON 80ED includes a fully multicoated objective lens made of extra-low dispersion (ED) glass housed in a sleek black tube. Throw in a nicely machined dual-speed Crayford focuser that accepts both 1¼" and 2" eyepieces, a retractable dew cap, and a 2" enhanced mirror star diagonal, and you have a portable instrument that's ready to take you to the stars.

$699.95

Takahashi TSA-102S

Takahashi's 4-inch f/8 TSA-102S is the first of a line of Triplet Super Apochromatic refractors that use a three-element objective to eliminate false color and spherical aberration. Whether used for lunar, planetary, or deep-sky observing, the TSA-102S produces amazing images.

Interested in a little photography? The TSA's oversized focuser is strong enough to support even the heaviest CCD cameras.

And with a tube that collapses to only 23 inches (58.4cm) long, the TSA-102S is ideal for airline travel.

$2,695

Orion SkyView Pro EON 80ED

Takahashi TSA-102S

Vixen ED115S

Tele Vue NP-101is

The 4-inch f/5.4 Tele Vue NP-101is houses a two-element full-aperture objective. Teamed with a two-element sub-aperture doublet at the back of the tube, this scope produces textbook-perfect stars across the full field of view. Add to the mix incomparable mechanics, including a precision focuser designed to meet the needs of today's digital imagers, and you get a top-notch visual telescope and a versatile imaging system all in one package.
$3,985

Tele Vue TV-102iis

The TV-102iis, based on the 4-inch f/8.6 TV-102 apochromatic optical system, is one of the most adaptable telescopes sold today. While it's great as a traditional visual telescope, the TV-102iis can accommodate a binocular viewer without an auxiliary transfer lens. But the real beauty of the scope is its optimized design for deep-space imaging, thanks to the large number of available adapter tubes and optical accessories. Indeed, the TV-102iis is a telescope for all seasons.
$2,985

Vixen ED115S

The 4.5-inch f/7.7 ED115S is the largest of four two-element ED apochromatic refractors sold by Vixen. As always, Vixen's optics and mechanics are world-class. The images through the ED115S are sharp and free of aberrations, while all mechanical parts work to perfection. The ED115S is available on several different Vixen mounts, from the economical Great Polaris-E (GP-E) to the heavier duty Great Polaris-D2 mount.
$2,599

Reflectors

Astro-Tech 6RC

While Ritchey-Chrétien telescopes are common in professional observatories, the design used to be prohibitively expensive for most backyard stargazers. That is, until Astronomy Technologies introduced the affordably priced 6-inch f/9 6RC. Its fully baffled tube and enhanced optical coatings combine to yield razor-sharp views of planets and deep-sky objects. The 6RC also comes with a dual-speed 2" Crayford focuser and a Vixen-style dovetail rail for attaching the 13-pound (5.9 kg) scope to many of today's most popular equatorial mounts.
$795

Astro-Tech 6RC

Tele Vue NP-101is

Tele Vue TV-102iis

Phil Harrington *is a contributing editor of* Astronomy *and a full-fledged telescope junkie.*

Celestron C8-NGT

Celestron's lineup of Newtonian reflectors includes the 8-inch f/5 C8-NGT on the CG-5GT computerized mount. Readers may recall that I tested this telescope/mount combination for the August 2004 issue of *Astronomy*. That scope had some of the finest optics I have ever seen in a Newtonian reflector. The C8-NGC comes with Celestron's fine 9x50 finder scope, a 2" focuser, and NexStar computer control technology with a 40,000-object database.

$1,019

Mag One 8 PortaBall

Meade LightBridge16

Mag One 8 PortaBall

Looking for something a little different in a Newtonian reflector? Consider the Mag One Instruments 8-inch f/5.5 PortaBall. Rather than just copying conventional design, Mag One built the PortaBall 8 around a hollow fiberglass sphere that houses the primary mirror. A pair of black-anodized metal rings and a short tube segment of a composite material make up the telescope's upper cage assembly, while six aluminum truss tubes join it to the primary's mirror ball. Many owners find that the PortaBall's axisless design makes it easier to track the sky by hand at higher magnifications than with conventional Dobsonians.

$2,995

Celestron C8-NGT

Meade LightBridge 16

Looking for a large reflector that you can take out to dark country skies in your small car? Meade's LightBridge family of telescopes is ideal if both room and budget are tight. Each scope's open truss design is easy to set up and tear down quickly without tools. Even the 16-inch f/4.5 can fit into most small cars. Best of all, LightBridge optics are exceptional, delivering classic images even at high magnifications. Smooth altitude- and azimuth-movement and a 2" focuser make each LightBridge a joy to use.

$1,849

Obsession Ultra Compact 18

If you're looking for a large-aperture instrument that breaks down into the smallest possible package for transportation, an Obsession Ultra Compact (UC) reflector might fit the bill. When fully collapsed, the 18-inch f/4.2 UC's "Virtual Mirror Box" — containing the primary mirror, altitude bearings, mirror cell, and associated hardware — measures only 24" by 24" by 13.5" (61cm by 61cm by 34cm). The upper tube assembly, designed to nestle into the mirror box for transport, adds only another 6 inches (15cm) to the stored height. But when set up, these instruments give the same world-class performance that Obsession has been famous for since owner Dave Kriege introduced the Obsession 1 in 1989.

$6,895

Obsession Ultra Compact 18

Adam Block/Mount Lemmon Sky Center/
University of Arizona

Orion StarBlast 6

Orion XT10 IntelliScope

Sometimes, it's nice to have a helping hand when aiming toward sky targets. Orion's 10-inch f/5 XT10 IntelliScope comes equipped with a pair of built-in encoders that connect to an optional object locator to help point the way. After selecting a celestial object from the computerized locator's memory, directional arrows guide you toward your target. Push the telescope around until the numbers next to the arrows read 0.0, and the target will be in view.

$499.95

Orion Skyquest XX12

Orion StarBlast 6

The StarBlast 6 is perfect for an astronomy-on-the-go lifestyle. Like its smaller sibling, the StarBlast 4.5, the StarBlast 6 is small enough to carry in one hand — mount and all — while clutching charts and references in the other hand. The larger 6-inch f/5 aperture is about 10 pounds (4.5 kg) heavier than the 4.5-inch, but it also serves up fainter deep-sky objects that escape unnoticed through the smaller instrument. Simply park the scope on a sturdy support, and it's ready to use.

$249.95

Orion Skyquest XX12

Orion's 12-inch f/4.9 Skyquest XX12 telescope packs the high-quality optics we've come to expect from Orion into a nicely designed truss-tube Newtonian. This scope is much easier to pack into the back of a car than conventional solid-tube instruments. You won't need tools to assemble the XX12, thanks to captive hardware secured to all four pairs of truss tubes. Once up and running, the XX12's 2" dual-speed Crayford focuser, smooth altitude and azimuth bearings, and the included IntelliScope object locator make viewing faint fuzzies a pleasure.

$1,299.95

Sky-Watcher 10-inch Dob

Orion XT10 IntelliScope

Sky-Watcher 10-inch Dob

Sky-Watcher's Dobsonians, including the 10-inch f/5 scope, are "telescoping telescopes." Rather than using triangular trusses, Sky-Watcher employs three parallel strut supports to bridge the gap between the primary mirror and focuser tube assemblies. Loosen the thumb knobs, and both halves of the telescope collapse together for transport. When you arrive at your observing site, pull the halves apart, retighten the thumb knobs, and the scope is ready to use. It's a simple, yet elegant, design that works well.

$595

Tony and Daphne Hallas

Stargazer Steve Truss Tube 6 kit

Vixen R200SS

Zhumell 10-inch Dob

Stargazer Steve Truss Tube 6 kit

Nowadays, we all enjoy out-of-the-box stargazing. Buy the telescope, set it up, and observe. Thirty years ago, most amateurs made their own telescopes. Amateur telescope maker Steve Dodson (Stargazer Steve) fondly remembers those days. He offers prefabricated telescope kits that take the angst out of building one from scratch while still offering the same feeling of accomplishment. Six aluminum poles attach between the mirror box at the telescope's base and the instrument's focuser assembly. A collapsible wooden tripod raises the entire instrument off the ground. Count on everything to fit together perfectly because Dodson personally assembles each instrument before shipment.

$599

Starmaster Hybrid Truss 11

Starmaster Newtonians are famous for exceptional optical and mechanical quality. One of their most popular instruments, the 11-inch f/4.3 Hybrid Truss, combines a respectable aperture in a package that breaks down for easy transport. The Hybrid's eight truss poles come preassembled in four trapezoidal pairings that make setup quick. In fact, you can leave the truss poles attached to the upper cage assembly and lift the entire unit onto the mirror box to make things go even faster.

$3,995

Starmaster Hybrid Truss 11

Vixen R200SS

The 7.9-inch f/4 R200SS reflector makes a great instrument for either wide-field viewing or imaging. As with all Vixen scopes, optical quality is outstanding. The R200SS comes on one of two German equatorial mounts. Choose from the solid GP-D2 or the state-of-the-art Sphinx go-to mount. The Sphinx comes with Vixen's Starbook go-to controller. The Starbook features a self-contained computerized planetarium program that graphically displays where the telescope is aimed — no charts required.

$1,599

Zhumell 10-inch Dob

If your telescope needs are basic, then the 10-inch f/5 Dobsonian-mounted Newtonian reflector marketed by Zhumell may be your best choice. The Zhumell 10 echoes John Dobson's original philosophy: Keep it simple. Zhumell doesn't use fancy materials. Instead, it has a straightforward telescope with great optics. Each comes with a 2" Crayford focuser with a 1¼" adapter, 32mm and 9mm eyepieces, and a Zhumell laser collimator.

$499

Catadioptrics

Celestron NexStar 6SE

One of the lightest, most compact instruments sold today is Celestron's 6-inch f/10 NexStar 6SE Schmidt-Cassegrain telescope. The XLT enhanced optics in the N6SE produce sharp images of everything in view, whether you're observing a planet, the Moon, a double star, or a faint deep-sky object. Aiming

Celestron NexStar 6SE

Celestron CPC925 GPS

the scope is a breeze, thanks to Celestron's NexStar go-to computer system built into the one-armed mount. Once initialized, it will accurately steer from target to target, even after a cross-sky slew.
$999

Celestron CPC925 GPS

Celestron's 9.25-inch f/10 Schmidt-Cassegrain is an exceptional telescope optically. Stars appear tack-sharp with outstanding contrast that really brings out subtle planetary detail. This excellence is due in part to the 9.25's f/2.5 primary. Other SCTs use primary mirrors with focal ratios around f/2. That slight difference results in a flatter field that many consider more aesthetically pleasing. The GPS-enabled CPC mount is remarkably sturdy, making it an ideal platform for both visual and photographic pursuits.
$2,199

Meade 10-inch LX200ACF GPS

This telescope may look like a Schmidt-Cassegrain on the outside, but it's a different story inside the Meade 10-inch f/10 LX200ACF GPS. All of Meade's Advanced Coma-Free (ACF) telescopes use a proprietary optical design optimized with advanced astrophotographers in mind. The ACF optics prevent star-bloating, a common complaint among today's imagers. Instead, stars appear as pinpoints across the full field of view. And the celebrated LX200ACF GPS go-to mount is great for astrophotography as well as for just looking around the universe.
$3,699

Meade 10-inch LX200ACF GPS

Meade ETX-125PE

Meade's ETX-125 Premiere Edition Maksutov has superb optical quality. Big brother to the famous ETX-90PE, the 5-inch f/15 ETX-125PE is just right for anyone looking for a compact telescope. The ETX-125PE comes emplaced on a miniature fork mount that includes Meade's acclaimed Autostar computerized go-to system. While the ETX-125 is small and light enough to place on a table for viewing, Meade's #884 Deluxe Field Tripod offers a sturdy support.
$899

Meade ETX-125PE

Orion Atlas 190 EQ-G

If you're looking for a versatile telescope that's just as appropriate for photographing wide-field deep-sky objects as it is for viewing the Moon and planets, then Orion's 7.5-inch f/5.3 Maksutov-Newtonian, the Atlas 190, should be on your list of possibilities. While some similarly sized Mak-Newts sell for more than $3,000, Orion's Atlas 190 costs less than that. Don't interpret the lower price as meaning a compromise in quality, however. The Atlas 190's well-corrected optics yield sharp star images, whether seen through a super-wide eyepiece or recorded with a digital camera.
$2,534.95

Orion Atlas 190 EQ-G

Observing Basics

by Glenn Chaple

Re-create a Galilean scope

Experience firsthand the telescope the famous astronomer used to survey the sky.

Four centuries ago this month, the Italian astronomer Galileo Galilei learned of a remarkable "toy" invented by a Dutch spectacle-maker the year before. Called a spyglass, this hollow tube with glass lenses at either end could make distant objects appear closer. Galileo quickly set out to design and construct one of his own. At first he was interested in the military potential of the gadget, but he soon used it as a way to bring the heavens closer.

The classical Galilean telescope collected incoming light with a convex objective lens and then magnified the image with a concave eyepiece. This combination produced the right-side-up view we see in binoculars but with an extremely narrow field of view.

Curious to experience firsthand what it might be like to ply the heavens with a telescope optically similar to Galileo's, I decided to assemble one for myself. Browsing the Internet, I came across two web sites dedicated to Galilean telescopes — Tom Pope's in-depth look at the subject (http://www.pacifier.com/~tpope) and the Rice University Galileo Project (http://galileo.rice.edu/lib/student_work; click on "astronomy 96/" and scroll down to "Making a Galilean Telescope"). Besides providing detailed instructions for assembling a Galilean telescope, both sites include historical background and descriptions of the landmark observations Galileo made.

Because I'm not particularly adept at the fine art of grinding and polishing glass, I ordered lenses from a company listed on Pope's site (he includes a table of lenses for both objective and eyepiece). Deciding on a meter-long 20 power telescope, I opted for a plano-convex objective with a 1,000mm focal length and a 50mm focal length plano-concave eyepiece. Both lenses were 1 inch (25mm) in diameter.

L MART
RETURNS
JIM PICKETT 7/92
©1992 Pickett/Heyn
LET ME GET THIS STRAIGHT, MR. GALILEO, YOU SAY IT SHOWS JUPITER'S MOONS, BUT NOT SATURN'S RINGS ?

Theoretically, the two should work as a unit if spaced 950 millimeters apart, which would mean mounting them in a tube of that approximate length. To be safe, I went to a local hardware store and purchased a 4-foot (1.2 meters) section of 1½-inch PVC pipe material. As luck would have it (the good kind, for a change), I found that 1½-inch black foam pipe insulation serves as ideal lens-holding material.

Back home, I carefully mounted the lenses by inserting them in 2-inch lengths of pipe insulation, then placed these lens units at opposite ends of the tube. By trial-and-error testing, I cut the PVC pipe to a length that would correctly position the lenses for a sharp focus on distant objects. I mounted each of the lenses with the curved side facing out.

I didn't make a mount. (Memo to self: Make a mount. This sucker is hard to aim!) Instead, I propped the "Galileo 2009" against my car and aimed it moonward. Four centuries after Galileo, I discovered the Moon's craters. Another discovery: The field of view is really tiny. I could see only a small portion of the Moon. I then observed the Pleiades — one star at a time. The field of view is really, *really* tiny! Using a Galilean scope gave me a genuine appreciation for the patience Galileo surely possessed. Had I been in his place, I would have been stamping through the streets of Padua cussing and fuming and blaming my problems on the light pollution generated by a candle someone placed on a nearby balcony!

Now it's your turn to make a Galilean telescope. I'm withholding detailed instructions because I want you to design your own. The web sites I mentioned will steer you in the right direction. Decide what magnification you want, as well as your telescope tube length, and then select the appropriate lenses. PVC pipe worked great for me, but a cardboard mailing tube is another option. The foam pipe insulation I used suffices as a temporary lens holder, but you may want to design something more permanent. Oh yes, make a mount!

Galileo's home-built telescopes were inferior in optical quality even to the "junky" 60mm refracting telescopes often seen on the market today. Last June, I described ways to modify one of those scopes to optimize its performance. An excellent article "Hot Rod 60mm Refractor," by Art Russell, appears in the archives of "Skywatch," the newsletter of the Northeast Florida Astronomical Society (NEFAS). You can access this nifty "how-to" by going to the NEFAS web site (www.nefas.org) and clicking on "Skywatch." Look for the June 2007 (labeled "06 2007") edition. Thanks to club member Ted Treiber for calling my attention to this neat little nugget.

Next month: We visit the Moon in June. Clear skies!

Binocular Universe

by Phil Harrington

Survey the southern sky

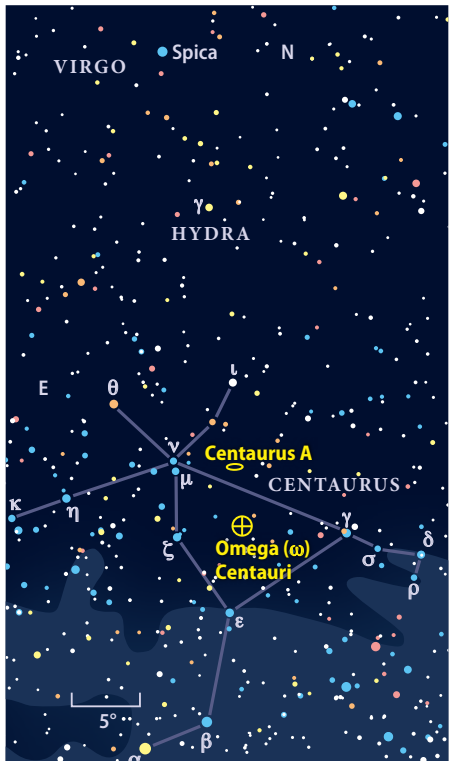
Two deep-sky objects in Centaurus challenge Northern Hemisphere observers.

On August 4, 1826, Scottish astronomer James Dunlop discovered what would prove to be a puzzle for the ages. While observing with his 9-foot reflecting telescope from Parramatta, New South Wales, Dunlop found what he later described as "a very singular double nebula. ... These two nebulae are completely distinct from each other, and no connection of the nebulous matters between them." A singular double nebula? Sounds more like an astronomical oxymoron than an observation. What had Dunlop found?

Dunlop's riddle is now known as **Centaurus A** (NGC 5128), a fascinating galaxy in the southern constellation Centaurus the Centaur. When we look at Centaurus A, we are looking at a case of galactic cannibalism. Inside the heart of this huge elliptical galaxy lies a massive black hole that is consuming a smaller spiral galaxy. The two are believed to have collided between 160 and 500 million years ago.

Your binoculars won't detect any of the internal strife that Centaurus A is enduring, but they can show you this intergalactic enigma that continues to fascinate astronomers — that is, if you can see the galaxy at all. The problem is that Centaurus A lies 43° south of the celestial equator, and so it is always confined to the far southern sky for most of the Northern Hemisphere. It never rises more than 7° above my own horizon here on Long Island (40° north latitude). Farther north, its maximum altitude shrinks; travel southward and Centaurus A will climb higher in the sky.

Overlooking the Atlantic Ocean along Long Island's south shore, I can just make out Centaurus A through my 10x50 binoculars. It's tough, but by waiting until it lies on the meridian and is highest in the sky, it's unmistakable.



Centaurus lies in the far southern sky for people in the Northern Hemisphere. Spotting the constellation's two deep-sky targets, Centaurus A and Omega (ω) Centauri, is a good challenge for binocular observers. *Astronomy:* Roen Kelly

As luck would have it, the bright star Spica (Alpha [α] Virginis) has nearly the same right ascension as the galaxy, so we can use it as a guide. Scan about 12° (two fields of view) straight southward from Spica to 3rd-magnitude Gamma (γ) Hydrae. Another 13° farther south, you will come to 3rd-magnitude Iota (ι) Centauri. It won't be long now.

Look for the 4th-magnitude star HD 117440 to Iota's southeast and then a distinctive triangle of stars — formed from Nu (ν), Mu (μ), and Phi (ϕ) Centauri — farther southeast still. Those latter three suns all lie at the same declination as the galaxy, so if you can see them, the galaxy is waiting for you. Place HD 117440 on the northern edge of your binocular field and Nu and Mu toward the east. Look carefully along the western side of the field and you should see the galaxy's faint, fuzzy disk. With 70mm and larger binoculars, you might be able to glimpse the mysterious dark band that slices across the galaxy.

If you found Centaurus A, then the night sky's grandest globular cluster of all, **Omega (ω) Centauri** (NGC 5139), lies just 4½° farther south. Can you spot it, too? I've seen 2nd-magnitude Zeta (ζ) Centauri, which lies at the same declination as Omega, from Long Island but never the cluster itself.

From a vantage point that places it high in the sky, Omega Centauri is a sight to behold. The finest view I have ever had was from the Winter Star Party in the Florida Keys several years ago. It was absolutely stunning! My first thought when I saw it: It's huge! I could resolve some of its estimated 1 million stars with 11x80 binoculars, while a "not-quite-resolved" grainy appearance was plainly evident through 10x50s. Regardless of the instrument used to spot it, you'll remember your first encounter with Omega Centauri for a lifetime.

This month concludes my "Binocular Universe" column here in *Astronomy* magazine. I hope you have enjoyed the journeys we have shared over these past 4 years and that you will continue to tour the universe through binoculars far into the future. Let's keep in touch. Drop me a line at phil@philharrington.net and share your observations. And until we meet again somewhere under the stars, remember that, now as always, two eyes are still better than one.

Discover more southern-sky targets at www.Astronomy.com/toc.

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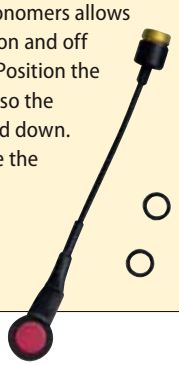
Mead, Washington



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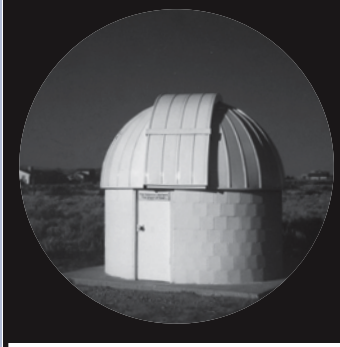

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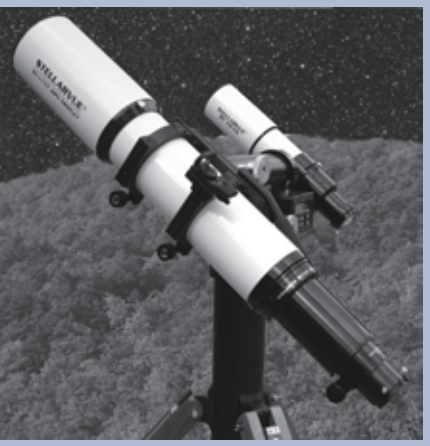

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by Michael E. Bakich

Brian Deis

President, Vixen Optics

Brian Deis shows off one of Vixen's most popular achromatic refractors, the ED80Sf. Vixen Optics; background image Adam Block/NOAO/AURA/NSF

Brian Deis was an accomplished observer long before he joined Vixen Optics. His eye for innovative optics and products has propelled the company to new heights and helped it weather the current economic downturn.

Brian grew up in New Jersey minutes from Manhattan, greatly limiting the stars he could see at night. An altar boy, he also assisted his father who worked at the local church.

"My parents, thinking I was on the path to the ministry, sent me to a religious retreat for one summer weekend," he says. "One moonless, cloudless night I was walking across an open field. I looked up and for the first time saw the Milky Way stretched out. I remember saying, 'What is that?'" At that moment, Brian started on a quest to understand the universe.

He fulfilled a lifelong goal when he built his Chester, New York, observatory. That facility featured a 16-inch telescope. There, Brian was able to show visitors the wonders of the universe. He left it behind to move to California. Even now, though, as the Vixen Optics president, he's living his dream.

Tell us about the most popular models you now have on the market.

Our most popular product is the R130, a 5-inch Newtonian reflector on the Porta mount. It combines a good aperture and a short-focal-length optical tube with the best slow-motion mount. It lets beginners view not only bright objects but also, with 5 inches of aperture, galaxies and nebulae.

The most talked-about product is the Sphinx SXD EQ mount. Vixen's exclusive STAR-BOOK controller has a database of tens of thousands of objects and an interactive star chart.

Tell me something cool about Vixen nobody knows.

Few people know that Vixen was named after one of Santa's reindeer. The Japanese tend to name things after nature, and the founder thought of Santa in his sleigh on a starry night.

Another tidbit is that Vixen's chairman is a Shinto priest. A large shrine sits on top of the factory. Understanding the background of the person that runs a company helps me understand Vixen's focus on customer satisfaction and happiness to users of its products.

*"Few people know that Vixen was **named after one of Santa's reindeer.**"*

How has Vixen changed through the years?

Years ago, Vixen primarily made products for companies like Orion and Celestron. Now, through Vixen Optics, consumers can buy products that carry the Vixen brand name and the included 5-year warranty.

Do you enjoy observing? Anything specific?

I've been observing for 35 years, and my wife can attest that I still get excited when I head out. We live on the California coast, so I get a nice view of the setting Sun, the Moon, and planets through binoculars.

My favorite targets are galaxy clusters. When I have the chance for some deep-sky viewing, I'll use the Vixen VMC330L or my 20-inch Dobsonian-mounted reflector.

Lastly, nothing compares to a public star party. Showing a beginner Saturn or the Hercules Cluster for the first time and hearing the inevitable "Oh, wow!" always makes me smile. It warms my heart when you have newbies that stay late because they just can't get enough viewing.

Can you share anything about upcoming products?

The New Porta II mount will be available soon. It has a head you can detach and mount on any of our other tripods.

Where, in your opinion, is the hobby headed?

It seems the hobby skipped a generation. People influenced by the Apollo missions grew the hobby in the 1970s and '80s. Their children, however, were caught up in the beginning of the Internet. But now this age group are bringing their children to star parties.

For growth to continue, clubs must break the mold of thinking that you must be an over-50 male to want to observe. Many young people, once introduced to a naked-eye view, will want to see more and more.

NEXT MONTH
in the June issue

Astronomy: Chuck Braasch

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How to see another universe
Our universe may form one bubble of many in a vast multiverse.

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A new technique called astrocombing will rewrite cosmologists' measure of cosmic expansion.

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Illustrated: How a concept called a celestial sphere makes the sky and its motions understandable.

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Astronomy magazine's new Online Reader Gallery is a collection of spectacular images — like Jim Lafferty's M42 (at left) — submitted daily from astrophotographers around the world. Categories include Comets, Galaxies, Nebulae, Planets, Star Clusters, Sun and Moon, and Other.

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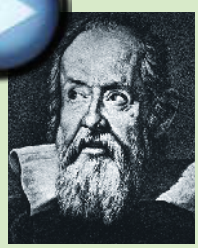

"The day Galileo changed the universe"

Featured video
"The day Galileo changed the universe, part one" — *Astronomy* magazine Editor David J. Eicher talks about how Galileo turned a telescope toward the Moon. **Astronomy.com/videos**

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NGC 1491 (24-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 180, 30, 20, and 30 minutes, respectively) • Adam Block/Mount Lemmon Science Center/University of Arizona

Stellar winds blow strongly

Emission nebula NGC 1491 (above) lies in the constellation Perseus just a bit more than 1° north-northwest of the magnitude 4.3 star Lambda (λ) Persei. The 3'-wide nebula has an 11th-magnitude star at its center. Note how the star is creating an irregularly shaped bubble in the gas that immediately surrounds it. The star's radiation excites the nebula's gas to glow red while winds of particles from this star are so energetic that they break up the nebula to the left of the star.

The Mare Humorum basin and the walled plain Gassendi stand out as some of the most prominent features of the southwestern quadrant of the Moon's nearside. (12.5-inch Gladius CF-315 telescope, LVI-1392 PRO CCD camera, Edmund Optics red filter, best 40 of 2,000 0.031-second exposures, taken February 17, 2008, beginning at 21h06m UT) • Paolo Lazzarotti, Massa, Italy

The Moon, Venus, and Jupiter dominate the sky as a fog bank covers Santa Monica, California, and the Pacific Palisades. Venus is the brighter of the two objects near the Moon. (Canon 5D digital SLR, Canon EF 24-105mm f/4 lens set at 32mm and f/5.6, ISO 800, 15-second exposure, taken December 1, 2008, at 5:56 P.M. PST) • Robert Commagere, Los Angeles

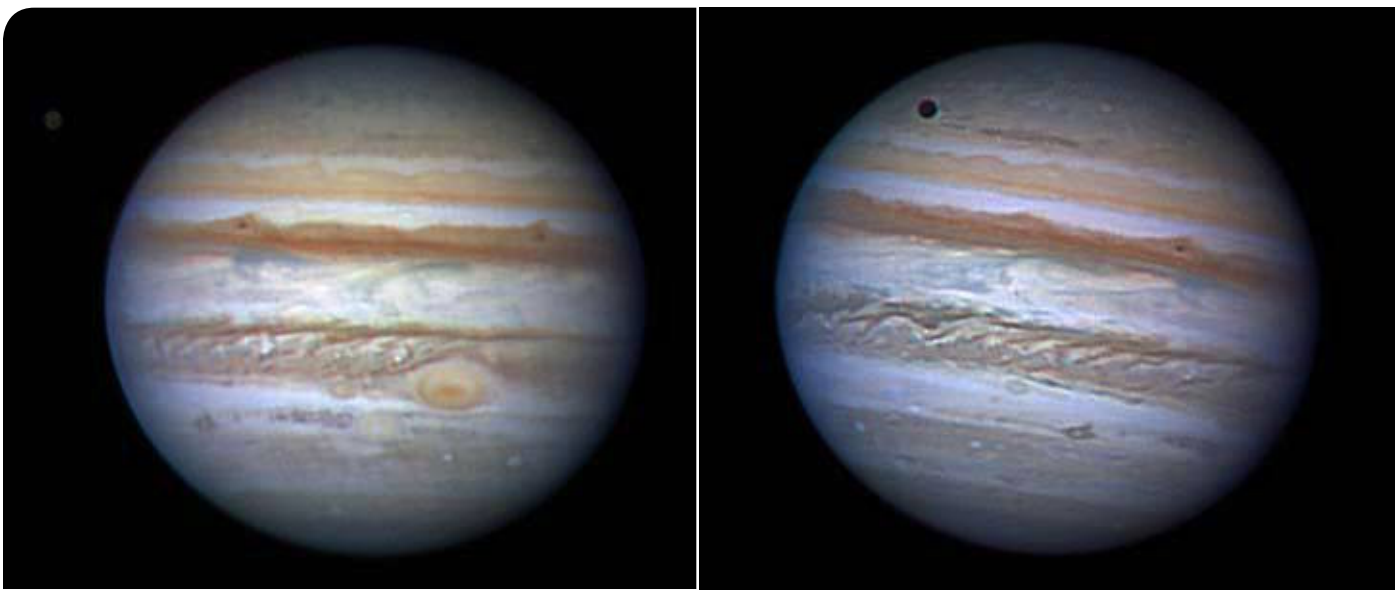
reader gallery

reader gallery

> Sharpless 2–64, a bright red emission nebula, offers a fine sight through almost any telescope. You'll need some patient imaging, however, to pick up the faint bluish reflection nebulosity. (8-inch Intes Maksutov-Newtonian telescope at f/4, SBIG ST-10XME CCD camera, HαRGB image with exposures of 360, 45, 45, and 45 minutes, respectively) • Dean Salman, Tucson, Arizona

V The Toby Jug Nebula (IC 2220) is a reflection nebula in Carina. Its bipolar structure gives it the shape of an old English drinking vessel. (10-inch ASA Astrograph at f/3.8, FLI Microline 8300 CCD camera, RGB image with exposures of 2,800, 2,000, and 2,800 seconds, respectively) • Gerald Rhemann, Vienna, Austria

> Spiral galaxy NGC 5985 in Draco spans 5.5' and glows softly at magnitude 11. It sits 1.9° east-northeast of 3rd-magnitude Iota (ι) Draconis. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG ST-10XME CCD camera, LRGB image with exposures of 170, 50, 50, and 50 minutes, respectively) • John Smith, Tucson, Arizona



^ Callisto lies next to Jupiter in the left image. Callisto appears dark when silhouetted against the planet's bright clouds in the right image. (12-inch Newtonian reflector, Imaging Source DMK21AU04 CCD camera, taken May 30, 2008, at 14h41m UT and 17h05m UT, respectively) • Mike Salway, Wyoming, Australia

< Spiral galaxy NGC 3938 in Ursa Major is a classic face-on spiral. It glows at magnitude 10.9. (12.5-inch Optical Guidance Systems Ritchey-Chrétien telescope, SBIG ST-10XE CCD camera, LRGB image with exposures of 301, 60, 60, and 60 minutes, respectively) • Ted Wolfe, Naples, Florida

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

The Orion Nebula (M42) ranks as many observers' favorite deep-sky object. (24-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 55, 25, 25, and 25 minutes, respectively) • Adam Block/Mount Lemmon Science Center/University of Arizona

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VISAC System- Vixen Sixth Order Aspherical Catadioptric	Yes	No	No
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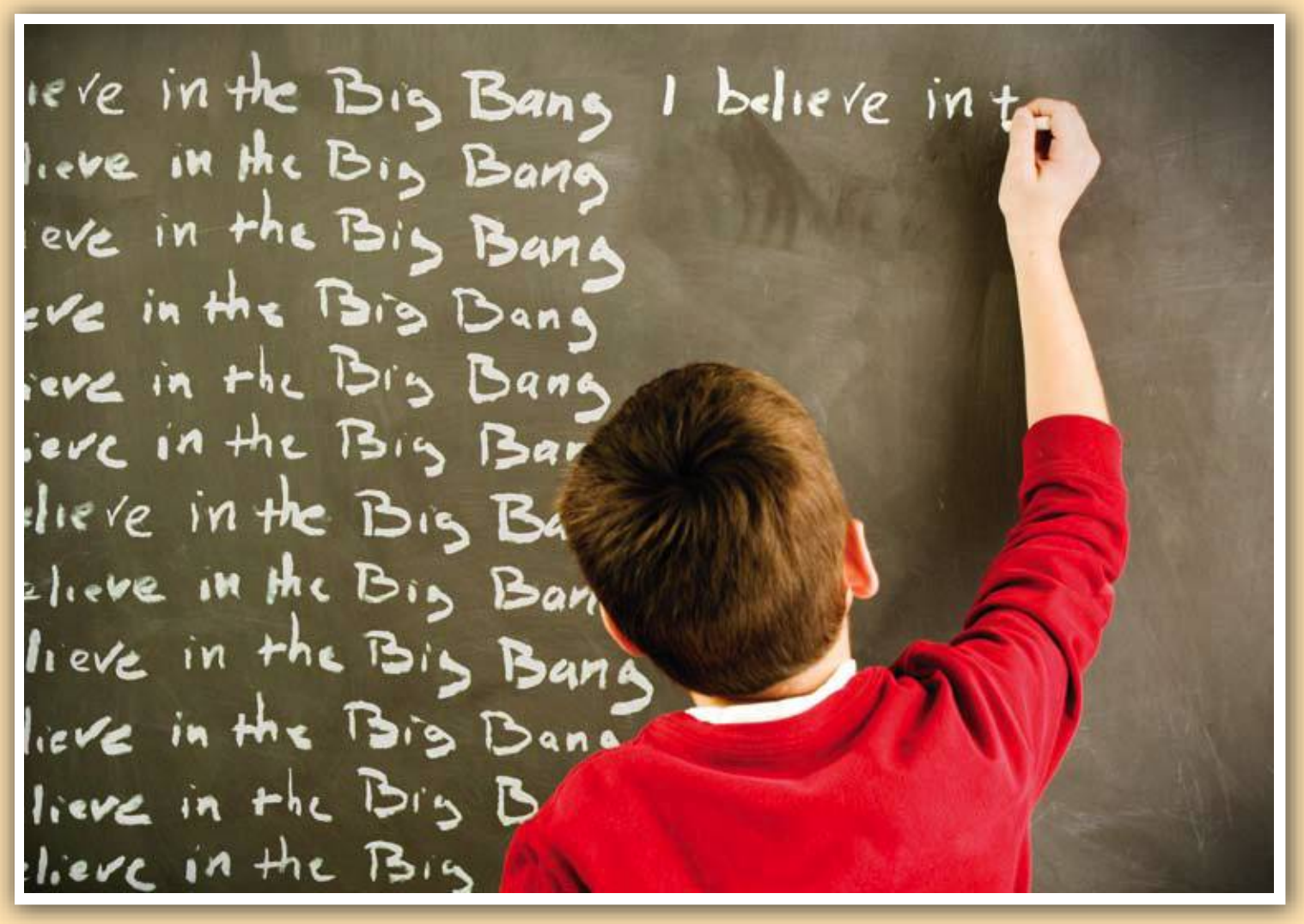

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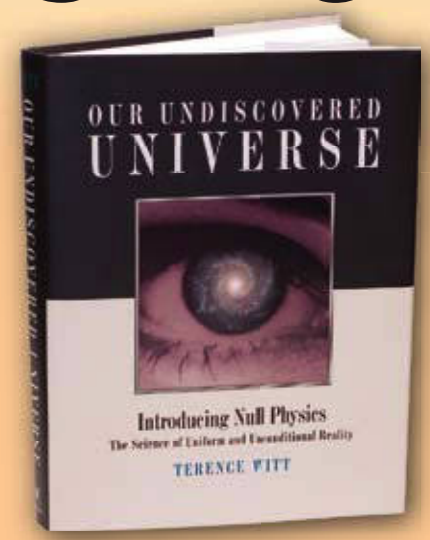

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